FIBER-OPTIC ROTATION SENSORS pdf

1: Optical fiber - Wikipedia

A fiber optic sensor system may contain many fibers where each fiber may contain many FBG sensors. Immune to interference from electromagnetic fields and do not electrically disturb other devices. Suitable for harsh environments.

All fiber optic components are employed in the system for directing the light to and from the loop and establishing, maintaining and controlling proper polarization of the light. In one particularly preferred embodiment, the loop and other components are formed on a single strand of fiber optic material which extends continuously through the system. Description This invention pertains generally to gyroscopes, interferometers and other instruments for sensing rotation, and more particularly to a rotation sensor of the type employing a sensing loop of fiber optic material. In Sagnac gyroscopes and other fiber optic rotation sensors counter propagating waves are generated in a loop of fiber optic material with a phase relationship corresponding to the rate at which the loop is rotated. Systems of this nature heretofor provided have employed bulk optical components for processing and directing the light applied to the sensing loop. While these devices provide a substantial improvement over other types of rotation sensors, they are subject to certain limitations and other disadvantages. For example, the various components must be aligned with each other within very close tolerances for the systems to perform properly, and this critical alignment can be difficult to establish and maintain in a practical system which is subjected to mechanical vibration, thermal change and other physical disturbances. It is in general an object of the invention to provide a new and improved fiber optic rotation sensor which overcomes the foregoing and other disadvantages of systems employing bulk optical components. Another object of the invention is to provide a rotation sensor of the above character which utilizes fiber optic components for guiding and processing the light applied to the sensing loop. Another object of the invention is to provide a rotation sensor of the above character in which the sensing loop and the components for guiding and processing the light are formed along a continuous, uninterrupted strand of fiber optic material. These and other objects are achieved in accordance with the invention by providing a rotation sensor having a light source, a loop of fiber optic material, an output detector, and all fiber optic components inter-connecting the source, loop and detector. Fiber optic directional couplers split the light from the source into two waves which propagate around the loop in opposite directions, combine the counter propagating waves for transmission along a single fiber, and apply the counter propagating waves to the output detector. Proper polarization of the applied light and the counter propagating waves is established, controlled and maintained by a fiber optic polarizer and fiber optic polarization controllers, ad the applied light and counter propagating waves are modulated in phase to eliminate the effects of backscatter and other noise in the system. In one particularly preferred embodiment, the loop, couplers, polarizer, polarization controllers and phase modulators are all formed along an uninterrupted strand of fiber optic material which extends continuously throughout the system. As illustrated in FIG. In one presently preferred embodiment, the light source comprises a helium-neon laser which produces light having a wavelength on the order of 1. The fiber optic material is preferably a single mode fiber having, for example, an outer diameter of microns and a core diameter of 9 microns. The loop comprises a plurality of turns wrapped about a spool or other suitable support not shown , and in one presently preferred embodiment, the loop has approximately turns of fiber wound on a form having a diameter of 16 cm. The loop is preferably wound with the central turns on the inside and the outer turns on the outside so that the winding is symmetrical and disturbances due to environmental changes e. In addition, the fiber is freely accessible at both ends of the loop, rather than having one end portion brought out from the inside of the loop. The winding is done by forming the fiber into two supply rolls, each comprising approximately one half of the fiber. Then, starting at the center, the fiber is wound from the two rolls onto the spool in opposite directions to form the loop. As the winding builds up on the spool, the two ends are always on the outside. Light from source 11 is coupled to one end of a fiber 13 by a lens Fiber 13 is a single mode fiber similar to the fiber from which loop 12 is formed, and in the embodiment illustrated it is an extension of the fiber which forms the loop. The portions of the fiber near the ends of the loop are brought together to form a bidirectional fiber optic coupler. This coupler serves to split the light from source 11 into two waves W1 and W2 which propagate around the loop in opposite directions. The coupler also serves to combine the two counter propagating waves from the loop for transmission back along fiber portion 13a toward the light source. After passing through coupler 16, end portion 13c terminates nonreflectively. A preferred fiber optic directional coupler for use in the rotation sensor of the invention is illustrated in FIG. This coupler and a method of manufacturing the coupler are described in detail in copending application Ser. The coupler comprises two strands 17 of single mode fiber optic material having the cladding removed from one side thereof. The two strands are brought together with the portions of the strands where the cladding has been removed in close facing relationship to form a region 18 of interaction in which light is transferred between the core portions of the strands. The amount of material removed is such that the core portion of each strand is within the evanescent field of the other, and the center-to-center spacing between the strands at the center of the coupler is typically less than about core diameters. Strands 17 are mounted in slots 21 which open through flat, confronting faces 22 of generally rectangular fused quartz blocks Slots 21 have arcuately curved bottom walls 24, and the fiber optic strands are affixed to the blocks so that they follow the contour of these walls. Thus, the strands converge toward the center of the blocks and diverge toward the edges of the blocks. In coupler 16, the light from source 11 is applied to port A, and this light is split approximately equally between ports B and D so that counter propagating waves W1 and W2 are approximately equal in magnitude. The two counter propagating waves applied to ports B and D contribute equally to the interference or output wave at port A. The output wave emerging from port A of coupler 16 is sensitive to the difference between the phases of the two counter propagating waves from which it is formed in that the amplitude of the output wave corresponds to the phase difference between the counter propagating waves. To eliminate phase shifts other than those due to rotation of the loop, it is important to detect only those portions of the waves which travel the same optical path. This insures that slow changes in the optical path due to environmental conditions e. For light which exits from coupler 16 through the same port through which it enters, the geometric path of both counter propagating waves is the same. In addition, the "polarization path" can be made the same by utilizing a single state of polarization for the input and output waves. Means is provided for establishing, maintaining and controlling a desired state of polarization for both the applied light and the counter propagating waves. This means includes a fiber optic polarizer 26 and fiber optic polarization controllers 27, 28 connected between light source 11 and loop Polarizer 26 is connected between the light source and port A of coupler 16, and polarization controller 27 is connected between the light source and the polarizer to control the polarization of the applied light or input wave. Polarization controller 28 is connected between port B of coupler 16 and one end of the loop to control the polarization of the counter propagating waves and, hence, the output wave. By means of controller 27, the state of polarization of the applied light is adjusted for efficient passage by polarizer 26, and controller 28 is adjusted for efficient passage of the waves returning from the fiber loop. Even though controller 28 is located on one side of the loop, it controls the state of polarization of both of the counter propagating waves. A preferred polarizer for use in the rotation sensor of FIG. This polarizer and a method of manufacturing the same are described in detal in copending application Ser. This polarizer includes a birefringent crystal 31 positioned within the evanescent field of light transmitted by fiber 13, the crystal providing different wave velocities for light of different polarizations. The relative indices of refraction of the fiber and the birefringent material are selected to be such that the wave velocity of light of the desired polarization mode is greater in the birefringent material than in the fiber and the wave velocity of an undesired polarization mode is greater in the fiber than in the birefringement material. Light of the desired polarization mode remains guided by the core portion of the fiber, whereas light of the undesired polarization mode is coupled from the fiber to the birefringent material. The crystal is brought within the evanescent field of the fiber by removing the cladding from one side of the fiber and positioning the crystal close to the core in this region. The slot has an arcuately curved bottom wall 36, and the fiber is affixed to the block so that it follows the contour of the bottom wall. In manufacture, the fiber strand is mounted in the slot, and the upper surface of the block and the fiber are ground simultaneously to remove the cladding in region Thereafter, crystal 31 is mounted on the block, with the lower surface 38 of the crystal facing the upper surface 33 of the block. Polarization controllers 27, 28 are identical, and a preferred polarization controller for use in the rotation sensor of FIG. This polarization controller is described in detail in copending application Ser. Between adjacent ones of the blocks, spools are mounted on shafts which are axially aligned and rotatively mounted in the blocks. The spools are generally cylindrical, and they are positioned tangentially of the shafts, with the axes of the spools perpendicular to the axis of the shafts. Strand 13 extends through axial bores in shafts and is wrapped about spools to form three coils The radii of the coils is relatively tight e. The three coils can be rotated independently about the axis of the shafts to adjust the polarization of light passing through the strand. Means is provided for modulating the phases of the counter propagating waves to bias the output signal and thereby improve the sensitivity of the system and provide an indication of the direction of rotation. This biasing is desirable because the portions of the counter propagating waves from the loop which are passed by the polarizer add in phase to a maximum value when the sensing loop is at rest. At this maximum, the output signal has low sensitivity to small phase differences between the interferring waves, and it does not indicate the direction of rotation. The means for modulating the counter propagating waves comprises a phase modulator 61 connected between coupler 16 and one end of loop A modulating signal is applied to the modulator by an AC generator operating at a suitable voltage level and frequency, e. The latter provide a biased signal which on a high frequency carrier avoids low frequency electronic noise. The bias so defined is independent of the stability of the amplitude of the modulation, the laser power and the fiber birefringence. An output detector responsive to the difference in phase between the two counter propagating waves provides an output signal corresponding to the rate of rotation of sensing loop This detector comprises a photodiode 66 and a lock-in amplifier The output wave passing through polarizer 26 varies in amplitude in accordance with the phase difference of the counter propagating waves, and this wave is coupled to the photodiode by a second fiber optic bidirectional coupler 68 which is similar to coupler However, rather than utilizing two portions of strand 13, coupler 68 employs a separate output strand 69 to which the output wave passing through polarizer 26 is applied. One end of this strand is coupled to the photodiode, and the other end is terminated nonreflectively. As illustrated, controller 27 is connected to port A of coupler 68, polarizer 26 is connected to port B, photodiode 66 is connected to port C, and there is no connection to port D. Photodiode 66 responds to the amplitude of the output wave from coupler 16 to provide an electrical signal corresponding to the difference in phase between the counter propagating waves. This signal is applied to the input of lock-in amplifier 67, and a reference signal is applied to the lock-in amplifier from AC generator The lock-in amplifier functions as a synchronous detector to provide an output signal corresponding to the rate of rotation of the sensing loop. A second phase modulator 71 is provided between light source 11 and polarization controller 27 to modulate the relative phases of the applied light and noise in the system and thereby average the parasitic interference and reduce the environmental sensitivity of the system. A difference in phase results from this modulation since the noise and the desired signal have different propagation times in the system. Modulator 71 is similar to modulator 61, and a modulating signal is applied to modulator 71 by an AC generator Alternatively, phase modulator 71 can be located at the midpoint or center of loop 12 rather than at the input of the system, and in some applications this position is preferred because it affects more noise components than a modulator located toward one end of the system. In the embodiment illustrated, a single strand of fiber optic material extends continuously through the system, and all of the fiber optic components loop 12, couplers 16, 68, polarizer 26, polarization controllers 27, 28 and phase modulators 61, 71 are formed directly on this strand. Alternatively, the fiber optic components can be formed separately and spliced together, e. However, the use of an uninterrupted strand throughout the system is preferred because it eliminates transmission loss in the splices and noise due to reflections from the splices. In one presently preferred embodiment, loop 12 is formed on a spool having a diameter of 16 centimeters and a width of about 10 centimeters, and the fiber optic components are mounted in a cavity in the body of the spool. This provides a compact instrument which is rugged in construction and capable of performance equal to or better than rotation sensors utilizing bulk optical components. Operation and use of the rotation sensor can be described briefly as follows. Loop 12 is positioned coaxially of the axis about which rotation is to be sensed. Light from source 11 passes through modulator 71, polarization controller 27, coupler 68 and polarizer 26 to coupler 16 where it is split into counter propagating waves W1, W2. These waves pass through polarization controller 28 and phase modulator 61, propagate around the loop, and return to coupler 16 with a difference in phase corresponding to the rate of rotation of the loop. Interference of the counter propagating waves in coupler 16 results in an output wave which varies in amplitude in accordance with the difference in phase between the counter propagating waves. This output wave is directed to polarizer 26, from which it passes through coupler 68 to photodiode The photodiode provides an electrical signal corresponding to the difference in phase, and this signal is applied to lock-in amplifier 67 to provide an output signal corresponding to the rate of rotation of the loop. Polarization controller 28 and polarizer 26 assure that the detected portions of the counter propagating waves will have a single state of polarization, and polarization controller 27 adjusts the polarization state of the input light for maximum transmission by the polarizer.

2: Fiber optic sensor - Wikipedia

A fiber optic sensor is a sensor that uses optical fiber either as the sensing element ("intrinsic sensors"), or as a means of relaying signals from a remote sensor to the electronics that process the signals ("extrinsic sensors"). Fibers have many uses in remote sensing.

The FOG is a robust, reliable, maintenance-free electro-optical device offering all advantages of the optical sensing technology. The gyro main frame is made of aluminum alloy or hard plastic to withstand a wide temperature range and high levels of vibration and shocks. Plastic housing option gives the gyroscope the lowest weight in its size. The technology provides the highest quality of the assembly with ZERO excess loss due to the absence of joints between components. By fine optical tuning the assembly may acquire immunity to electromagnetic interference eliminating the need for heavy shielding. A single miniature analog PCB performs all necessary functions to process the optical signal and provide stability and precision conforming to the performance of the optical assembly. The open-loop FOG architecture is illustrated by the above Figure. Then the light passes through a polarizer and a spatial filter which ensure the reciprocity of the counter-propagating light beams through the fiber coil. Another coupler I splits the two light beams in the fiber optic coil where they pass through a harmonic modulator PZT. The modulator is offset from the center of the coil to impress a relative phase difference between the counter-propagating light beams. Synchronous demodulation behind the detector converts the rotationally-induced first harmonic signal into a rate proportional voltage. Analog Output Some general properties of the open-loop gyroscope may be deduced from fundamental physical principles. No dead zone or hysteresis. The Sagnac phase responds to rotation nearly instantly and without distortions. That is why the relation between the output voltage and the input angular rate is perfectly proportional. In some ways, the open-loop gyro is an ideal sensor of rotation. Sagnac phase delay is 0. Bias immunity to acceleration gravity. Constant acceleration does not create any phase difference between counter-propagating waves of the ring interferometer. Analog Electronics Design The open-loop sensor requires electronics to control SLD current and PZT voltage for signal conditioning and for precise demodulation of the interferometric signal after its conversion from the optical power to the receiver voltage.

3: USA - Multimode fiber optic rotation sensor - Google Patents

Since then the field of fiber optic rotation sensors has grown so rapidly that a conference devoted primarily to this subject was needed. The First International Conference on Fiber-Optic Rotation Sensors was held at the Massachusetts Institute of Technology, Cambridge, Massachusetts, Nove~Â- ber ,

A multimode light source such as a light emitting diode can be used. The system is economical and environmentally stable. This invention relates generally to rotation sensors such as gyroscopes, and more particularly the invention relates to a fiber optic rotation sensor. Optical gyroscopes employing ring interferometers are known which can perform the function of mechanical gyroscopes. Presently, much effort is being directed to producing technically and commercially feasible fiber optic rotation sensors which would be more compact, lightweight, and inexpensive than conventional ring interferometers which employ mirrors. Optical gyroscopes utilize the Sagnac effect in a ring interferometer. The fiber optic rotation sensor has a length of optical fiber wound in coils around an area. In the presence of rotation of the coil, counter-directional optical waves propagating around the coils experience the Sagnac phase shift. This is a relativistic phenomenon since the time for light to travel through the fiber is longer in one direction than in the other direction due to the rotation of the coils. The intensity of the combined light is a function of the phase difference between the two light waves which travel the same path but in opposite directions, and the output of a light detector is proportional to the intensity of the combined light. Heretofore, a single transverse mode polarized light beam has been split and applied to the fiber loop as the contradirectional optical waves. However, a non-rotationally induced differential phase shift is present in such fiber optic rotation sensors if the polarization in the optical fiber is not conserved or controlled. This phase shift is caused by residual birefringence in the optical fiber. The phase shift can be quite large and very sensitive to the environment. While the phase shift can be minimized or eliminated by correct use of a polarization analyzer, environmentally produced amplitude variations or scale factor variations can still remain. The unpolarized light permits the non-reciprocal phase shift between the counter propagating waves to be eliminated without employing a polarization analyzer or other special equipment. An object of the present invention is an improved method of sensing rotation through use of fiber optics. Another object of the invention is an improved fiber optic rotation sensor. Yet another object of the invention is a fiber optic rotation sensor having improved power coupling and reduced coherent back scattering and reduced non-linear effects. Still another object of the invention is a fiber optic rotation sensor having increased environmental stability. Another object of the invention is a fiber optic rotation sensor which is economical to produce. A feature of the invention is a rotation sensor which utilizes a multimode light wave which is transmitted through a multimode optical loop. Applicants have discovered that the advantages in using unpolarized light in a single mode system can be realized in a multimode system, also, using unpolarized light, along with the attendant advantages derived from using a multimode source and optical fiber including an improved power coupling and reduced back scattering along with economy of fabrication. The invention and objects and features thereof will be more readily apparent from the following detailed description and appended claims when taken with the drawing, in which: Referring now to the drawings, FIG. Heretofore the realization of the output characteristics of FIG. The residual birefringence can be large and very sensitive to the environment. Further, the single mode optical fibers are not only expensive, but also the input power coupling is difficult and a significant amount of coherent back scattering of light exists. The single mode linearly polarized light from the source 10 is applied through a beam splitter 14 and modal filter 16 to the beam splitter Beam splitter 18 directs two identical waves through the coil 12 in opposite directions, and the waves recombine at the beam splitter 18 and are then passed through modal filter 16 and the beam splitter 14 to a photodiode detector The detector responds to the intensity of the combined waves which depends on the differences in phase between the two counter propagating waves to provide an output signal as illustrated in FIG. Importantly, since the average value is at the point of maximum slope of the response curves, increased accuracy in measuring the phase shift is realized. In this embodiment a multimode source 30 generates a multimode, unpolarized light beam which passes through the directional coupler 32 to a beam splitter The two multimode unpolarized light beams from the beam splitter 34 are then passed in opposite directions through the multimode fiber coil shown generally at 36, similar to the embodiment of FIG. After passing through the coil 36 the two beams are recombined and transmitted through the directional coupler 32 to the photodiode detector Importantly, the multimode source can be a semiconductor device, such as an LED, and again because of the larger numeric aperture of the multimode fiber, increased power coupling is achieved. Reduced coherent back scattering is also achieved by the spatial incoherence of the modes. Since neither a modal filter nor a polarization analyzer is required, the insertion losses therefrom are eliminated. Following is an analysis of both the polarized and unpolarized fiber optic rotation sensors. The electric field in the multimode fiber can be expanded in the N modes of the fiber as EQU1 where Mk x,y is the kth mode and ak z is a complex number representing the amplitude and phase of the kth mode. For quasi-monochromatic light, the correlation between the modes must be specified along with the power in the mode. The klth term is J. The optical fiber is modeled as a 2N port linear system. The ports are identified with the fiber modes at either end of the fiber. The fiber is described by two transfer matrices T21 and T12 which characterize propagation from end 1 to 2 and vice versa. The transfer matrices are unitary if the fiber is lossless. A transfer matrix for the gyroscope can be written in terms of the transfer matrices of the components. Consider the two configurations of multimode fiber gyros described hereinabove, one using polarized light FIG. For polarized light all of the power is in one mode i. Note that the response curves are sinusoidal with the positions of the maxima and minima of each curve independent of Tkl. This indicates reciprocal behavior. For the polarized gyro, the value of the minima are fixed while the value of the maxima depends on Tkl. In the unpolarized gyro, the average value of the curves is constant, while the maxima and minima expand or contract uniformly about the average value depending on Tkl. Thus the behavior of polarized and unpolarized multimode gyros has the same basic characteristics as for polarized and unpolarized single mode gyros. For the polarized gyro, FIG. However, individual modes are sometimes well preserved, which would result in reduced insertion loss. The insertion loss of the unpolarized gyro, FIG. All N modes are detected. The large numerical apertures of multimode fibers allow more optical power to be coupled into them than into single mode fibers. This can be important in reducing the effects of detector noise. Also coherent backscattering and environmental sensitivity are lower because of averaging over the modes. While the invention has been described with reference to specific embodiments, the description is illustrative of the invention and is not to be construed as limiting the invention. Various modifications and applications may occur to those skilled in the art without departing from the true spirit and scope of the invention as defined by the appended claims. A fiber optic rotation sensor comprising: The fiber optic rotation sensor as defined by claim 1 wherein said light source comprises a multimode light source. The fiber optic rotation sensor as defined by claim 2 wherein said light source comprises a light emitting diode.

4: USA - Fiber optic rotation sensor - Google Patents

Fiber-Optic Rotation Sensors and Related Technologies: Proceedings of the First KEYENCE FUU Fiber Optic Sensors FU59U Fiber Amplifier Sensor New in Box. Brand.

The Fotonic Sensor transmits a beam of light through a flexible fiber-optic probe, receives light reflected from a target surface, and converts this light into an electrical signal proportional to the distance between the probe tip and the target being measured. A simplified example of the fiber optic principal is shown in Figure 2. The output signal voltage from the fiber optic sensor is then used to determine position, displacement, vibration amplitude, frequency and waveshape of a target surface. It sets new performance standards with resolution up to 0. Figure 3 shows that when a fiber optic probe is mounted close to a target, the amount of reflected light A seen by the receiving fibers B2 is small. However, as the target moves further away from the probe Figure 4 , the amount of light illuminated on the receiving fibers B2 increases rapidly. Even small target movements in this range cause a significant increase in the amount of received light. Sensor reflected light is low, close to target Figure 3 Maximum reflected light from fiber optic sensor Figure 4 If you plot a curve of the voltage output proportional to the light intensity received verses the distance between the target and the fiber optic sensor you will find that the relationship is very sensitive when the probe is close to the target. This highly sensitive area is called the front slope of the performance curve Figure 5 , typical values as listed as Range 1 in Table 1. Fiber optic probe response curve Figure 5 Increasing the distance further causes the illuminated area A in Figure 4 to enlarge, increasing the amount of reflected light seen by the receiving fibers B2. Eventually, area B2 becomes saturated indicating that the fibers are accepting the maximum amount of light possible. This apex is called the optical peak. The displacement range over which the initial voltage rises and where the maximum output occurs is a function of the probe diameter and numerical aperture N. Adjusting the amplitude of the optical peak provides the output sensitivity required for inspection and comparison of surface conditions. It is also used to calibrate each fiber optic probe to duplicate the sensitivity factors established at MTII. Figure 6 shows three different reflective surfaces. Fiber optic probe response curves to different target reflectance Figure 6 Curve A: Instrument response curve if target reflectance is high. Calibrated instrument response curve. Instrument response curve if target reflectance is low. Note that the optical peak occurs at the same operating distance for each of the three samples. By adjusting the amplitude of this peak to match the amplitude set at MTII during the calibration process Curve B the front slope and back slopes can be replicated. This slope, or sensitivity value, is stored in the memory of the MTI plug in module and used to convert voltage to a displacement or position. If higher sensitivity is required the light intensity can be increased even further. For example, a 20X increase in lamp intensity proportionally increases the fiber optic probe sensitivity by 20X. This can easily be accomplished by electronic circuitry that monitors the lamp intensity via a silicon photodiode. The silicon photodiode is linear over several orders of magnitude light intensity so a wide range of sensitivities may be selected entirely by electronic control. Additionally, the lamp monitor photodiode can be used in an electronic servo control to keep the lamp intensity constant, ensuring a stable displacement reading. Further target movement away from the probe causes a loss of reflected light intensity seen by the receiving fiber B2 in Figure 4 and produces a decrease in the voltage output. This area of the curve is called the back slope region Figure 5 , typical values as listed as Range 2 in Table 1. Each plug-in module stores the sensitivity factor of the front and back slope providing two distinct operating regions per fiber optic sensor. One highly sensitive area with a small standoff and measurement range and another less sensitive area with a larger standoff and measurement range. This focuses the light from the fiber optic probe to a point about 0. KD-LS-1A fiber optic probe extender Figure 7 When the distance from the front of the KD-LS-1A to the reflecting target is approximately the same as the focal length of the lens assembly, an image of the probe face will appear on the surface of the reflective target. This causes the returning light to enter the transmitting fibers and significantly reduces the light projected onto the receiving fibers. KD-LS-1A fiber optic probe extender response curve compared to standard probe Figure 8 When the target distance is displaced slightly in either direction from the focal point, the image is blurred and the returning light begins to enter the receive fibers again. This action generates a peak in output signal at either side of the null. Other models of the Optical Extender can incorporate a magnification factor to obtain even greater sensitivity while still retaining the advantage of increased operating gap. Applying Fiber Optic Sensors Fiber-Optic Probes The key element of the Fotonic Sensor is the flexible fiber optic probe, which consists of two sets of fiber optic filaments jacketed together to form one. Active diameters can be as small as 0. To provide a wide variety of sensitivities and measurement ranges MTII provides three standard fiber optic probe configurations as shown in Figure 9. These configurations are determined by the distribution of the transmitting and receiving fiber optic filaments in the probe tip. Fiber optic probe configurations Figure 9 A random fiber distribution is a random mix of the transmitting and receiving fibers. Fiber optic sensors with a random fiber patterns demonstrate high displacement sensitivity because of the close interaction between neighboring fibers, but have a short measurement range. A hemispherical fiber distribution separates the transmitting and receiving fibers into two distinct groups, with one half of the probe tip composed of transmitting fibers and the other half all receiving fibers. Hemispherical probe tips offer a long range, but low displacement sensitivity. A concentric transmit inside fiber distribution contains a group of transmitting fibers located at the center of the probe tip surrounded by a concentric group of receiving fibers. Because of their symmetrical arrangement this style of probe is less affected by tilted targets. Figure 10 outlines the relative performance of the different fiber optic configurations. Relative performance of different fiber optic sensor configurations Figure 10 MTII also offers special fiber optic edge or shadow probes. In these arrangements the fiber distribution contains a transmit group of fibers opposing a receive group of fibers. Both transmit and receive bundles can be either random or hemispherical, depending on the application performance required. A thin or narrow target is placed in the gap between the fibers bundles. As a target moves between these bundles a shadow is cast on the receive fibers causing a change in light intensity received. Like standard fiber optic probes this converts to a change in the voltage output of the MTI Fotonic Sensor, which is related to the edge position. This configuration is particularly effective measuring runout of computer disks, magnetic tapes or displacement of thin ultrasonic horns. Bundle diameters range from 0. A typical response curve for a fiber optic edge probe Figure 11 In addition to using customized edge probes, standard fiber optic reflectance types can also be used to measure the lateral movement or vibration of a target edge. Since the optical peak is a point of inflection on the performance curve it is an area where the received light of the fiber optic sensor does not change with small target displacements. Taking advantage of this characteristic allows the sensor to be used to measure changes in reflectivity or position of an edge, independent of motion in the normal direction. By traversing a target across the probe face a unique output curve is generated and can be used to precisely determine position. Figure 12 shows two examples of the output from a fiber optic sensor verses lateral edge position. Note that different sensitivities can be obtained by orientating the probe 90 degrees. Different fiber distributions also produce different sensitivities, allowing sensors to fulfill a variety of application requirements. Fiber optic sensor response curve to lateral target motions Figure 12 Reflectance compensated fiber optic probes consist of three sets of fibers as shown in Figure The first set consists of a random bundle located in the center. Flanking this bundle are two sets of receive fibers, each with different numerical apertures. The two separate receive bundles permit compensation for different surface reflectivities, eliminating the need for calibration as is done with standard fiber optic probes. Because of their reflectance compensation ability they are particularly effective measuring displacements of targets that have lateral movement. Reflectance compensated probes also work through optical extenders, offering similar increases in the probe operating standoff, with the added benefit of reflectivity compensation. Typical response curve for a reflectance compensated fiber optic sensor Figure 13 The selection of a particular probe configuration depends on the application requirements. Table 1 outlines the performance of different probe diameters and fiber arrangements. A similar decrease in linear range also exists. It is also important to note that the signal to noise ratio increases with larger diameter fiber bundles. This is because of the increased number of fibers within the probe, resulting in improved light collection. Fiber optic probe module specifications Table 1 Custom probe configurations are available for specialized applications. This is useful for surface finish comparison and surface flaw-detection applications. Additionally, fiber optic sensors may be employed in pressure monitoring application where varying pressure changes the position or reflectance of a target. The non-contact, no-hysteresis characteristics of fiber optic sensors make them particularly suitable for transducers and high frequency applications. Fiber-optic sensors may also be operated in nearly any gaseous or liquid media.

5: OSA | Fiber-optic rotation sensor technology

FIBER OPTIC ROTATION SENSOR A MaJor Qualifying ProJect subaitted to the faculty of WORCESTER POLYTECHNIC INSTITUTE In partial fulfillaent of the raquireaant for the.

Intrinsic sensors[edit] Optical fibers can be used as sensors to measure strain , [1] temperature , pressure and other quantities by modifying a fiber so that the quantity to be measured modulates the intensity , phase , polarization , wavelength or transit time of light in the fiber. Sensors that vary the intensity of light are the simplest, since only a simple source and detector are required. A particularly useful feature of intrinsic fiber optic sensors is that they can, if required, provide distributed sensing over very large distances. Electrical voltage can be sensed by nonlinear optical effects in specially-doped fiber, which alter the polarization of light as a function of voltage or electric field. Angle measurement sensors can be based on the Sagnac effect. Special fibers like long-period fiber grating LPG optical fibers can be used for direction recognition [3]. Hydrophone systems with more than one hundred sensors per fiber cable have been developed. Both bottom-mounted hydrophone arrays and towed streamer systems are in use. The German company Sennheiser developed a laser microphone for use with optical fibers. Optical fibers can be made into interferometric sensors such as fiber optic gyroscopes , which are used in the Boeing and in some car models for navigation purposes. They are also used to make hydrogen sensors. Fiber-optic sensors have been developed to measure co-located temperature and strain simultaneously with very high accuracy using fiber Bragg gratings. The fiber used is designed such that the Faraday and Kerr effects cause considerable phase change in the presence of the external field. Electrical power can be measured in a fiber by using a structured bulk fiber ampere sensor coupled with proper signal processing in a polarimetric detection scheme. Experiments have been carried out in support of the technique. With FBG integrated technology, sensors can provide detailed analysis and comprehensive reports on insights with very high resolution. These type of sensors are used extensively in several industries like telecommunication, automotive, aerospace, energy, etc. The efficiency of fiber Bragg grating based fiber optic sensors can be provided by means of central wavelength adjustment of light emitting source in accordance with the current Bragg gratings reflection spectra. A major benefit of extrinsic sensors is their ability to reach places which are otherwise inaccessible. An example is the measurement of temperature inside aircraft jet engines by using a fiber to transmit radiation into a radiation pyrometer located outside the engine. Extrinsic sensors can also be used in the same way to measure the internal temperature of electrical transformers , where the extreme electromagnetic fields present make other measurement techniques impossible. Extrinsic fiber optic sensors provide excellent protection of measurement signals against noise corruption. Unfortunately, many conventional sensors produce electrical output which must be converted into an optical signal for use with fiber. For example, in the case of a platinum resistance thermometer , the temperature changes are translated into resistance changes. The PRT must therefore have an electrical power supply. The modulated voltage level at the output of the PRT can then be injected into the optical fiber via the usual type of transmitter. This complicates the measurement process and means that low-voltage power cables must be routed to the transducer. Extrinsic sensors are used to measure vibration, rotation, displacement, velocity, acceleration, torque, and temperature. Therefore, it is essential to exploit novel fiber-optic structures to disturb the light propagation, thereby enabling the interaction of the light with surroundings and constructing fiber-optic sensors. Until now, several methods, including polishing, chemical etching, tapering, bending, as well as femtosecond grating inscription, have been proposed to tailor the light propagation and prompt the interaction of light with sensing materials. In the above-mentioned fiber-optic structures, the enhanced evanescent fields can be efficiently excited to induce the light to expose to and interact with the surrounding medium. However, the fibers themselves can only sense very few kinds of analytes with low-sensitivity and zero-selectivity, which greatly limits their development and applications, especially for biosensors that require both high-sensitivity and high-selectivity. To overcome the issue, an efficient way is to resort to responsive materials, which possess the ability to change their properties, such as RI, absorption, conductivity, etc. Due to the rapid progress of functional materials in recent years, various sensing materials are available for fiber-optic chemical sensors and biosensors fabrication, including graphene, metals and metal oxides, carbon nanotubes, nanowires, nanoparticles, polymers, quantum dots, etc. Consequently, the surrounding changes will be recorded and interrogated by the optical fibers, realizing sensing functions of optical fibers. Currently, various fiber-optic chemical sensors and biosensors [21] have been proposed and demonstrated.

6: Fiber Optic Sensors for Displacement & Ultrasonic Vibration Measurements

The present list of citations is included in this proceeding for the convenience of the reader. It is only a chronological selection of titles extracted from our collection of papers on Optical Rotation Sensing.

Fiber-optic communication Optical fiber is used as a medium for telecommunication and computer networking because it is flexible and can be bundled as cables. It is especially advantageous for long-distance communications, because light propagates through the fiber with much lower attenuation compared to electrical cables. This allows long distances to be spanned with few repeaters. The net data rate data rate without overhead bytes per fiber is the per-channel data rate reduced by the FEC overhead, multiplied by the number of channels usually up to 80 in commercial dense WDM systems as of [update]. Fiber is also immune to electrical interference; there is no cross-talk between signals in different cables, and no pickup of environmental noise. Non-armored fiber cables do not conduct electricity, which makes fiber a good solution for protecting communications equipment in high voltage environments, such as power generation facilities, or metal communication structures prone to lightning strikes. They can also be used in environments where explosive fumes are present, without danger of ignition. Wiretapping in this case, fiber tapping is more difficult compared to electrical connections, and there are concentric dual-core fibers that are said to be tap-proof. For example, most high-definition televisions offer a digital audio optical connection. Advantages over copper wiring[edit] This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. May The advantages of optical fiber communication with respect to copper wire systems are: A single optical fiber can carry over 3,, full-duplex voice calls or 90, TV channels. Immunity to electromagnetic interference: Light transmission through optical fibers is unaffected by other electromagnetic radiation nearby. The optical fiber is electrically non-conductive, so it does not act as an antenna to pick up electromagnetic signals. Information traveling inside the optical fiber is immune to electromagnetic interference , even electromagnetic pulses generated by nuclear devices. Low attenuation loss over long distances: Attenuation loss can be as low as 0. Optical fibers do not conduct electricity, preventing problems with ground loops and conduction of lightning. Optical fibers can be strung on poles alongside high voltage power cables. Material cost and theft prevention: Conventional cable systems use large amounts of copper. Global copper prices experienced a boom in the s, and copper has been a target of metal theft. Security of information passed down the cable: Copper can be tapped with very little chance of detection. Fiber optic sensor Fibers have many uses in remote sensing. In some applications, the sensor is itself an optical fiber. In other cases, fiber is used to connect a non-fiberoptic sensor to a measurement system. Depending on the application, fiber may be used because of its small size, or the fact that no electrical power is needed at the remote location, or because many sensors can be multiplexed along the length of a fiber by using different wavelengths of light for each sensor, or by sensing the time delay as light passes along the fiber through each sensor. Time delay can be determined using a device such as an optical time-domain reflectometer. Optical fibers can be used as sensors to measure strain , temperature , pressure , and other quantities by modifying a fiber so that the property to measure modulates the intensity , phase , polarization , wavelength , or transit time of light in the fiber. Sensors that vary the intensity of light are the simplest, since only a simple source and detector are required. A particularly useful feature of such fiber optic sensors is that they can, if required, provide distributed sensing over distances of up to one meter. In contrast, highly localized measurements can be provided by integrating miniaturized sensing elements with the tip of the fiber. Extrinsic fiber optic sensors use an optical fiber cable , normally a multi-mode one, to transmit modulated light from either a non-fiber optical sensorâ€”or an electronic sensor connected to an optical transmitter. A major benefit of extrinsic sensors is their ability to reach otherwise inaccessible places. An example is the measurement of temperature inside aircraft jet engines by using a fiber to transmit radiation into a radiation pyrometer outside the engine. Extrinsic sensors can be used in the same way to measure the internal temperature of electrical transformers , where the extreme electromagnetic fields present make other measurement techniques impossible. Extrinsic sensors measure vibration, rotation, displacement, velocity, acceleration, torque, and torsion. A solid state version of the gyroscope, using the interference of light, has been developed. The fiber optic gyroscope FOG has no moving parts, and exploits the Sagnac effect to detect mechanical rotation. Common uses for fiber optic sensors includes advanced intrusion detection security systems. The light is transmitted along a fiber optic sensor cable placed on a fence, pipeline, or communication cabling, and the returned signal is monitored and analyzed for disturbances. This return signal is digitally processed to detect disturbances and trip an alarm if an intrusion has occurred. Optical fibers are widely used as components of optical chemical sensors and optical biosensors. A frisbee illuminated by fiber optics Light reflected from optical fiber illuminates exhibited model Optical fibers have a wide number of applications. They are used as light guides in medical and other applications where bright light needs to be shone on a target without a clear line-of-sight path. In some buildings, optical fibers route sunlight from the roof to other parts of the building see nonimaging optics. Optical-fiber lamps are used for illumination in decorative applications, including signs , art , toys and artificial Christmas trees. Optical fiber is an intrinsic part of the light-transmitting concrete building product LiTraCon. Optical fiber can also be used in structural health monitoring. This type of sensor is able to detect stresses that may have a lasting impact on structures. It is based on the principle of measuring analog attenuation. Use of optical fiber in a decorative lamp or nightlight Optical fiber is also used in imaging optics. A coherent bundle of fibers is used, sometimes along with lenses, for a long, thin imaging device called an endoscope , which is used to view objects through a small hole. Medical endoscopes are used for minimally invasive exploratory or surgical procedures. Industrial endoscopes see fiberscope or borescope are used for inspecting anything hard to reach, such as jet engine interiors. Many microscopes use fiber-optic light sources to provide intense illumination of samples being studied. In spectroscopy , optical fiber bundles transmit light from a spectrometer to a substance that cannot be placed inside the spectrometer itself, in order to analyze its composition. A spectrometer analyzes substances by bouncing light off and through them. By using fibers, a spectrometer can be used to study objects remotely. Rare-earth-doped optical fibers can be used to provide signal amplification by splicing a short section of doped fiber into a regular undoped optical fiber line. The doped fiber is optically pumped with a second laser wavelength that is coupled into the line in addition to the signal wave. Both wavelengths of light are transmitted through the doped fiber, which transfers energy from the second pump wavelength to the signal wave. The process that causes the amplification is stimulated emission. Optical fiber is also widely exploited as a nonlinear medium. The glass medium supports a host of nonlinear optical interactions, and the long interaction lengths possible in fiber facilitate a variety of phenomena, which are harnessed for applications and fundamental investigation. Optical fibers doped with a wavelength shifter collect scintillation light in physics experiments. Fiber-optic sights for handguns, rifles, and shotguns use pieces of optical fiber to improve visibility of markings on the sight. Principle of operation[edit] Play media An overview of the operating principles of the optical fiber An optical fiber is a cylindrical dielectric waveguide nonconducting waveguide that transmits light along its axis, by the process of total internal reflection. The fiber consists of a core surrounded by a cladding layer, both of which are made of dielectric materials. The boundary between the core and cladding may either be abrupt, in step-index fiber , or gradual, in graded-index fiber. Index of refraction[edit] Main article: Refractive index The index of refraction or refractive index is a way of measuring the speed of light in a material. Light travels fastest in a vacuum , such as in outer space. The speed of light in a vacuum is about , kilometers , miles per second. The refractive index of a medium is calculated by dividing the speed of light in a vacuum by the speed of light in that medium. The refractive index of a vacuum is therefore 1, by definition. A typical singlemode fiber used for telecommunications has a cladding made of pure silica, with an index of 1. From this information, a simple rule of thumb is that a signal using optical fiber for communication will travel at around , kilometers per second. To put it another way, the signal will take 5 milliseconds to travel 1, kilometers in fiber. The fiber in this case will probably travel a longer route, and there will be additional delays due to communication equipment switching and the process of encoding and decoding the voice onto the fiber. Total internal reflection When light traveling in an optically dense medium hits a boundary at a steep angle larger than the critical angle for the boundary , the light is completely reflected. This is called total internal reflection. This effect is used in optical fibers to confine light in the core.

FIBER-OPTIC ROTATION SENSORS pdf

Light travels through the fiber core, bouncing back and forth off the boundary between the core and cladding. Because the light must strike the boundary with an angle greater than the critical angle, only light that enters the fiber within a certain range of angles can travel down the fiber without leaking out. This range of angles is called the acceptance cone of the fiber. In simpler terms, there is a maximum angle from the fiber axis at which light may enter the fiber so that it will propagate, or travel, in the core of the fiber. The sine of this maximum angle is the numerical aperture NA of the fiber. Fiber with a larger NA requires less precision to splice and work with than fiber with a smaller NA. Single-mode fiber has a small NA. The propagation of light through a multi-mode optical fiber. A laser bouncing down an acrylic rod, illustrating the total internal reflection of light in a multi-mode optical fiber. Such fiber is called multi-mode fiber, from the electromagnetic analysis see below. In a step-index multi-mode fiber, rays of light are guided along the fiber core by total internal reflection. Rays that meet the core-cladding boundary at a high angle measured relative to a line normal to the boundary , greater than the critical angle for this boundary, are completely reflected.

7: OSA | Fiber-optic rotation sensors for seismic measurements

Fiber Optic Sensors. The fiber optic sensors also called as optical fiber sensors use optical fiber or sensing element. These sensors are used to sense some quantities like temperature, pressure, vibrations, displacements, rotations or concentration of chemical species.

8: What is a Fiber Optic Sensor?| Sensor Basics: Introductory Guide to Sensors | KEYENCE

The fiber optic rotation sensor has a length of optical fiber wound in coils around an area. In the presence of rotation of the coil, counter-directional optical waves propagating around the coils experience the Sagnac phase shift.

9: Orbitec Fiber Optic Rotation Mini-Sensor (FORMS) | www.enganchecubano.com

Some of the earliest fiber optic sensors were fiber optic rotation sensors (gyros) that were described and demonstrated in the 's. Fiber optic gyros are mature products, extremely accurate and reliable, and used primarily in high-end navigation systems as well as for geophysical drilling equipment guidance systems.

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