(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 March 2016 (31.03.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/046586 A1

(51) International Patent Classification:
G02B 6/44 (2006.01) *G02B 6/00* (2006.01)

(21) International Application Number:
PCT/IB2014/002207

(22) International Filing Date:
25 September 2014 (25.09.2014)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: AN OPTICAL CABLE WITH RETRACTABLE MODULES AND A METHOD FOR PRODUCING SAID MODULES

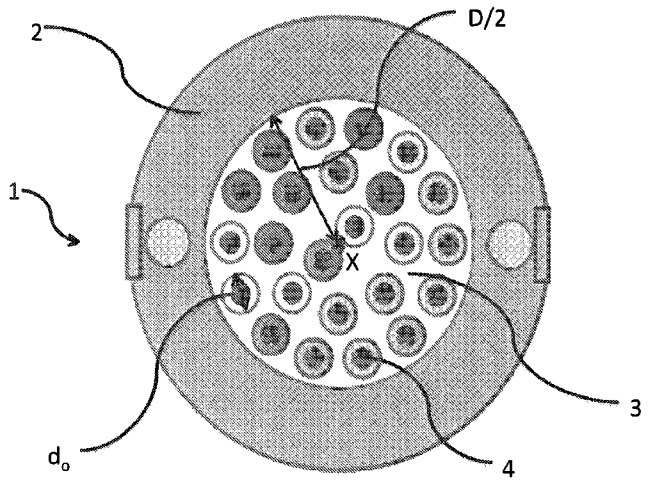


Figure 1

(57) Abstract: An optical cable (1) comprises a sheath (2) surrounding a cavity (3) and a plurality of substantially parallel modules (4) arranged into said cavity (3) with a filling ratio between 20 and 50%; each of said modules (4) comprises: • four to twelve fibers (9), • A tube (5) surrounding the fibers (9) that comprises a mix of polycarbonate and a low friction polymer, chosen from the group of fluorinated polymers and polyamide; said tube (5) having a ratio between its inner d_i and outer d_o diameters between 0.45 and 0.55, and comprising an outer low friction polymer layer (6) having a thickness between 0.05 and 0.15 mm, • A filling ratio of said module 4 greater than 55%.

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An optical cable with retractable modules and a method for producing said modules.

1. Technical Field

The present invention relates generally to the field of optical waveguide structure of the optical fiber type.

2. Background Art

Optical fibers are used to transmit information over long distances, at the speed of light in glass. In order to achieve successfully this mission, optical fibers and the corresponding optical waveguide structures must be able to resist to the potential alterations that may occur during the operational period of the fibers.

Moreover, deployment of optical fibers has shown a tremendous increase in the context of FTTx business (such as Fiber To The Home (FTTH), Fiber To The Curb (FTTC), ...). In this context, a specialty cable, filled with loose fiber modules that are designed to have low friction properties, is used as the core of the operation. Window-cuts can be made at multiple points along the cable length, so as to allow individual fiber modules to be cut and pulled back to one of those earlier window-cuts. These fiber modules can then be pushed or blown though separate micro-ducts to reach a termination or distribution point (typically on the customer premises).

It is important that such fiber modules have the flexibility to be pushed, pulled, bent, branched, and handled in ways that allow easy manipulation for installation, without reductions in loss or damage to the fiber core.

Patent document WO 2006/136558 discloses an optical fiber cable comprising: a protective sheath having an inner surface defining a cavity, one or more micro-cables or micro-tubes running inside the cavity, the or each micro-cable having an outer jacket, characterized in that the cross-sectional area of the micro-cables and micro-tubes is less than 75 % of the cross-sectional area of the cavity, and in that the outer jacket of a micro-cable or of a micro-tube is formed of a material having a dynamic coefficient of friction that, when measured according to test A, is less than or equal to 0.2 and having a Shore hardness greater than 65. This patent document describes parallel modules made of a mixture of Polycarbonate and Polybutylenteraphtalate in a cable, each

module containing one, two or four optical fibers. The external diameter of these modules is 1.4 mm.

Patent document FR 2 914 752, discloses a cable that has a longitudinal central cavity receiving a set of optical fiber micro modules arranged in a parallel manner, and a sheath surrounding the central cavity. A protection armor, e.g. steel strap, is arranged on an inner periphery of the sheath, and each micro module includes a maintaining sheath of an optical fiber surrounded by an external layer having friction coefficient higher than that of the maintaining sheath. It also discloses a method for extracting a micro module of an optical fiber telecommunication cable. This patent document describes parallel modules in a cable, each micro module containing 4 to 24 optical fibers. The external layer of the micro modules could be Polyamide.

Patent document US2005/0265673 discloses a communication cable buffer tube having a flexural modulus ranging from about $1.24*10^6$ to $1.93*10^6$ kPa (180 to 280 kpsi). Buffer tubes made of e.g. Polycarbonate, polyamide (such as nylon 12) and combinations thereof are also disclosed.

The Applicant of the present patent application, a subsidiary of Prysmian Group, operates an optical cable referenced as Retractanet© that comprises retractable fiber modules called PicoFlex© in which optical fiber bundles are embedded in a special soft hot melt. A layer of technical polymer such as polyamide is then extruded on the special hot melt layer. These modules own specific technical attributes regarding their thermal stability, low friction coefficient, tensile strength and strip ability, allowing the optical cable to be operational.

These modules are soft enough to be flexible and easy to handle, while at the same time being stiff enough to retract long distances within the cable and be pushed or blown through small micro-ducts as well.

However, there is a need for improving such an optical cable, in order for an operator to access more quickly to the optical fibers within the modules and to extract quickly and on a long distance said fibers from the cable.

More generally, it would be desirable to improve the fiber access of fibers contained in retractable modules, while keeping sufficient strength of the module to withstand the pulling forces during module extraction from the cable.

3. Summary

In one particular embodiment of the invention, an optical cable is disclosed, which comprises a sheath having an inner surface defining a cavity and a plurality of modules arranged into said cavity and targeted to be parallel, said cavity having a filling ratio between 20% and 50%. Said modules comprise:

- four to twelve fibers,
- A tube surrounding the fibers and made from a mix of polycarbonate (PC) and a low friction polymer, chosen from the group of fluorinated polymers and polyamide; said tube having a ratio between its inner and outer diameters between 0.45 and 0.55, and comprising an outer low friction polymer layer having a thickness between 0.05 mm and 0.15 mm,
- A filling ratio of said module greater than 55%.

In the following description, the expression "substantially parallel modules" or "modules targeted to be parallel" refers to modules that are non-(helical or SZ-)stranded or, in other words, to modules that are not winded up into a common strand. The "filling ratio of the cavity" is the total cross section of the optical modules divided by the cross section of the cable cavity, given in %. The filling ratio of the cavity is:

$$100 * N * (d_o/D)^2$$

With d_o the outer diameter of an optical module, N the number of modules in the cable and D the inner diameter of the cable.

By analogy, the filling ratio of the module is:

$$100 * N_f * (d_f/d_i)^2$$

With N_f the number of fibers in the module, d_f the outer diameter of said fibers and d_i the inner diameter of the module. Since the tube is the surrounding envelope of the module, the inner diameter of the tube is also the inner diameter of the module, and the outer diameter of the tube is also the outer diameter of the module.

In order to achieve good retractability over long lengths, the filling ratio of the cable according to the invention is restrained between 20 and 50%.

In addition, the control of the module-filling ratio above 55% allows improving the kink and tensile properties of the module.

According to the invention, modules are totally free in the cable. Hence, fibers in

these modules present excellent performances in attenuation and thermal stability, meeting most of the international standards.

The present invention also relies on a novel and inventive approach of both the composition and the conformation of the modules and induces several advantages and benefits.

First of all, the use of a mix of PC and a low friction polymer in the composition of the tube allows maintaining a satisfactory thermal stability within the module. Such a limitation of the thermal variations allows limiting the attenuation of the light signal carried by the optical fibers, improving as a consequence the efficiency of the optical cable. Such a low friction polymer is chosen from the group of fluorinated polymers and polyamide.

The covering of the PC by a thin layer of low friction polymer, such as PA for example, allows on a first hand to reduce the friction coefficient of the module. Thus, the low friction coefficient allows the pull back of the modules up to 200 m in the cable. On the other hand, the outer layer also protects the PC layer that is highly sensitive to the stress cracking. The outer layer therefore avoids the PC layer to be in direct contact with tension active materials such as solvents, which are able to alter its structure. Advantageously, the outer layer is watertight, what significantly reduces the module preparation time for splicing the fibers. In order to obtain the desired effect from the mix of low friction polymer and PC, the thickness of the outer layer is ranging from 0.05 to 0.15 mm. Indeed, an outer layer thickness above 0.05 mm allows for a good protection of the PC layer, while above a thickness of 0.15 mm, the share of PC is too low to be a satisfactory base material.

In other words, modules according to embodiments of the invention present a very low friction coefficient of 0.15 maximum and a tensile strength that allows applying on the module a pulling force during a pull back operation without breaking of the optical fiber.

A module according to embodiments of the invention presents a low sensitivity to the kink effect. This parameter is very important to be able to execute in the right way the pull back operations, and all further splicing operations. Since the increase of the ratio between the inner and outer diameters of the module is linked to the increase of the kink effect sensitivity, this ratio is carefully controlled between 45 and 55% in

order to keep the kink performances of the module optimal while leaving the necessary space within the module so that it can contains from four to twelve fibers.

Embodiments of the invention also contribute to improve the production phase of the module. The process is then characterized by a better control of the modules diameter and by a reduction of the occurrence of fiber breaks, lumps and scrap production, what allows to reduce the production costs. In addition, an extrusion speed of 300 m per minute can advantageously be reached.

Finally, the module according to embodiments of the invention allows an easy access to the fibers by the operator of the optical cable. In this matter, a simple ring cut at 1,5 m from the end of the module allows in one subsequent step and in a limited amount of time (a few seconds) extracting the fibers from the cable.

In one particular embodiment, the module comprises four or eight or twelve fibers.

The increase in the number of fibers N_f allows to comply with the minimum threshold of 55% defined for the filling ratio of the module as mentioned before.

Of course, notably for 4-fiber modules, some of the fibers may be dummy fibers, or non-functioning fibers, if less than four optical fibers are required. Such dummy fibers (which could be out of spec fibers) are required for the mechanical stability of the 4-fiber module.

The operator is therefore free to implement one to four optical fibers for each tube while keeping a satisfactory filling ratio in the 4-fiber module by the implementation of non-functioning (dummy) fibers.

According to an embodiment of the invention, for fibers having a diameter of 245µm ±10µm the outer diameter (d_o) of said modules is between 1.20 and 1.45 mm for a 4-fiber module, or between 1.55 and 1.9 mm for a 8-fiber module, or between 1.90 and 2.50 mm for a 12-fiber module.

According to another embodiment of the invention, for fibers having a diameter of 200µm ±10µm the outer diameter (d_o) of said modules is between 1.00 and 1.20 mm for a 4-fiber module, or between 1.25 and 1.55 mm for a 8-fiber module, or between 1.55 and 1.90 mm for a 12-fiber module.

According to an aspect of the invention, said tube is a coextruded polycarbonate and polyamide tube. Such a co-extrusion process allows for improved adhesion between

PC and PA layers, as compared to two separate extrusion steps.

According to yet another aspect, the tube surrounding the fibers is filled with a filling compound having a viscosity between 5000 and 7000 mPa.s at 25°C. Hence, the fibers are not bonded to the tube. This technical feature advantageously eases the process of the pull back operations.

In one particular embodiment, the filling compound is replaced with a swellable material, i.e. with a material having the ability to increase volume by absorption of solvent. This technical feature eases the fiber cleaning and reduces the preparation time for splicing the fibers.

According to another aspect, the module is watertight and totally dry.

This technical feature allows further reducing the module preparation time for splicing the fibers.

In one particular embodiment, at least one of said modules comprises four fibers and has an inner diameter of 0.65 mm and an outer diameter of 1.25 mm.

According to another aspect, the thickness of the outer layer is preferably 0.1 mm.

According to another aspect yet, the PA is a PA12 type polyamide.

According to yet another aspect, for at least one of said modules, said tube comprises four fibers and an inner polycarbonate layer having an inner diameter of 0.65 mm and outer diameter of 1.05 mm and an outer polyamide layer having an inner diameter of 1.05 mm and an outer diameter of 1.25 mm.

The selection of values and/or material for the inner and outer diameters of the module, the thickness of the PA layer and/or the composition of the PA, as described here above, allows obtaining an optical cable that features optimal technical performances in operation.

In one particular embodiment, at least two of said modules have outer layers with different colors.

Such a change of colors of the low friction polymer skins eases the identification of the different modules within the cable.

The invention also concerns a method for manufacturing an optical cable as described here above, which comprises a step of co-extrusion of the tube from a mix of low friction polymer, chosen from the group of fluorinated polymers and polyamide, and

PC.

This method allows improving the adhesion between the low friction polymer, such as PA, and PC layers, compared to a method comprising two separate extrusion steps. Said step of co-extrusion of the tube may be driven at a speed of at least 150m/min, preferably at least 300 m/min, more preferably at least 450m/min.

While not explicitly described, the present embodiments may be employed in any combination or sub-combination.

5. Brief description of the drawings

The invention can be better understood with reference to the following description and drawings, given by way of example and not limiting the scope of protection, and in which:

- Figure 1 is a schematic view of the cross section of a cable according to an embodiment of the invention;
- Figure 2 is a schematic view of the cross section of a module according to an embodiment of the invention.

The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

6. Description of an embodiment

The present invention relates to optical cables, modules and fibers. Many specific details of the invention are set forth in the following description and in **figures 1 and 2**. One skilled in the art, however, will understand that the present invention may have additional embodiments, or that the present invention may be practiced without several of the details described in the following description.

The foregoing is described in relation to a particular embodiment of the invention, in which modules comprise four fibers. It must be understood that modules according to the invention may also comprise eight or twelve fibers, although this is not described in the following exemplary embodiment.

Moreover, the following exemplary embodiment describes a co-extruded tube made from a mix of PC and PA. It must be understood that any other low friction

polymer may replace polyamide, notably a polymer chosen from the group of fluorinated polymers.

Figure 1 illustrates schematically an optical cable 1. Cable 1 is defined about an axis of revolution X that is orthogonal to the plan of **Figure 1**. Cable 1 comprises a sheath 2 that defines the outline of cable 1. This sheath 2 is a reinforced plastic tube and features a certain thickness which value is equal to the difference between its outer diameter and its inner diameter D. The sheath inner wall defines a cavity 3 in which a number N of modules 4 is arranged. Each of these modules 4 is defined about an axis of revolution Y that is substantially parallel to the axis of revolution X of cable 1. Each module 4 features an outer diameter d_o. According to the formula mentioned here above, the filling ratio within the cavity 3 is ranging from 20 to 50%.

Figure 2 illustrates schematically a module 4. This module 4 is defined about an axis of revolution Y that is orthogonal to the plan of **Figure 2**. Module 4 comprises a tube 5 that defines its outline. The inner diameter d_i of the tube 5 is 0.65 mm whereas its outer diameter d_o is 1.25 mm. Tube 5 is the result of the co-extrusion of an outer PA layer 6 and an inner PC layer 7, bonded one with the other. The respective thicknesses of the PA and PC layers are 0.1 and 0.2 mm. The tube's inner wall defines a cavity 8 in which four optical fibers 9 (N_f is then equal to 4) are arranged. The rest of the cavity is filled with an optical cable filling compound 10, whose viscosity is between 5000 and 7000 mPa.s at 25°C, such as cable gels marketed under the trade name Unigel©. Each of the optical fibers is defined about a revolutionary axis that is substantially parallel to the axis Y of module 4. Each fiber features an outer diameter d_f. According to embodiments of the invention and following the formula mentioned here above, the filling ratio within module 4 is above 55%.

As mentioned above, tests have been conducted in order to challenge the thermal stability of a module according to the invention. In this matter, 1 km of such module in a free coil has been operated under temperatures ranging between -30°C to +70°C. As a result, the change in attenuation of a light signal with a wavelength of 1625 nm has been measured under 0.15 dB/km for a fiber of the known G657A2–type (BendBright^{XS}© FTTH optical fiber, produced by Prysmian Group). Such a minimization of the light attenuation in an optical fiber is undoubtedly a major performance that distinguishes the module according to the invention from the prior art.

CLAIMS

1. An optical cable (1) characterized in that it comprises a sheath (2) having an inner surface defining a cavity (3) and a plurality of modules (4) arranged into said cavity (3) and targeted to be parallel, said cavity having a filling ratio between 20% and 50%,

each of said modules (4) comprising:

- four to twelve fibers (9),
- A tube (5) surrounding the fibers (9) and made from a mix of polycarbonate and a low friction polymer, chosen from the group of fluorinated polymers and polyamide; said tube (5) having a ratio between its inner (d_i) and outer (d_o) diameters between 0.45 and 0.55, and comprising an outer low friction polymer layer (6) having a thickness between 0.05 and 0.15 mm,
- A filling ratio of said module (4) greater than 55%.

2. The cable (1) according to claim 1, wherein said modules comprise 4 or 8 or 12 fibers.

3. The cable (1) according to claim 2, wherein for fibers having a diameter of 245µm ±10µm the outer diameter (d_o) of said modules is between 1.20 and 1.45 mm for a 4-fiber module, or between 1.55 and 1.9 mm for a 8-fiber module, or between 1.90 and 2.50 mm for a 12-fiber module.

4. The cable (1) according to claim 2, wherein for fibers having a diameter of 200µm ±10µm the outer diameter (d_o) of said modules is between 1.00 and 1.20 mm for a 4-fiber module, or between 1.25 and 1.55 mm for a 8-fiber module, or between 1.55 and 1.90 mm for a 12-fiber module.

5. The cable of any of claims 1 to 4, wherein said tube is a coextruded polycarbonate and polyamide tube.

6. The cable (1) according to any of claims 1 to 5, wherein said tube surrounding the fibers is filled with a filling compound (10) having a viscosity between 5000 and 7000 mPa.s at 25°C.

7. The cable (1) according to any of claims 1 to 5, wherein said tube surrounding the fibers is filled with a swellable material.

8. The cable (1) according to any of claims 1 to 7, wherein at least one of said modules (4) is watertight.

9. The cable (1) according to any of claims 1 to 8, wherein at least one of said modules comprises four fibers and has an inner diameter of 0.65 mm and an outer diameter of 1.25 mm.

10. The cable (1) according to any of claims 1 to 9, wherein the thickness of the outer layer (6) is preferably 0.1 mm.

11. The cable (1) according to any of claims 5 to 10, wherein said polyamide is a PA12 type polyamide.

12. The cable of any of claims 1 to 11, wherein, for at least one of said modules, said tube comprises four fibers and an inner polycarbonate layer having an inner diameter of 0.65 mm and outer diameter of 1.05 mm and an outer polyamide layer having an inner diameter of 1.05 mm and an outer diameter of 1.25 mm.

13. The cable (1) according to claims 1 to 12, wherein at least two of said modules (4) have outer layers with different colors.

14. A method for manufacturing an optical cable according to any of claims 1 to 13, wherein said method comprises a step of co-extrusion of the tube (5) from a mix of polycarbonate and a low friction polymer, chosen from the group of fluorinated polymers and polyamide.

15. The method of claim 14, wherein said step of co-extrusion of the tube is driven at a speed of at least 150m/min, preferably at least 300 m/min, more preferably at least 450m/min.

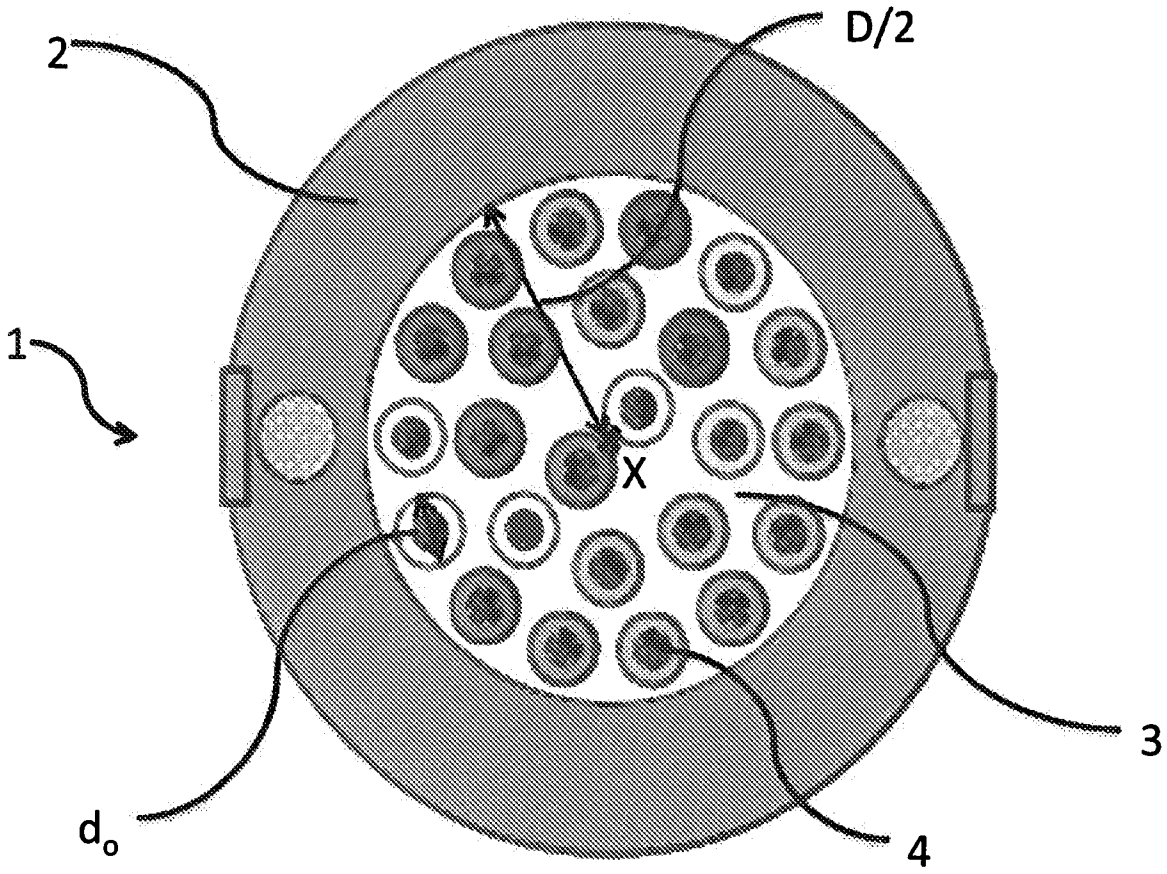


Figure 1

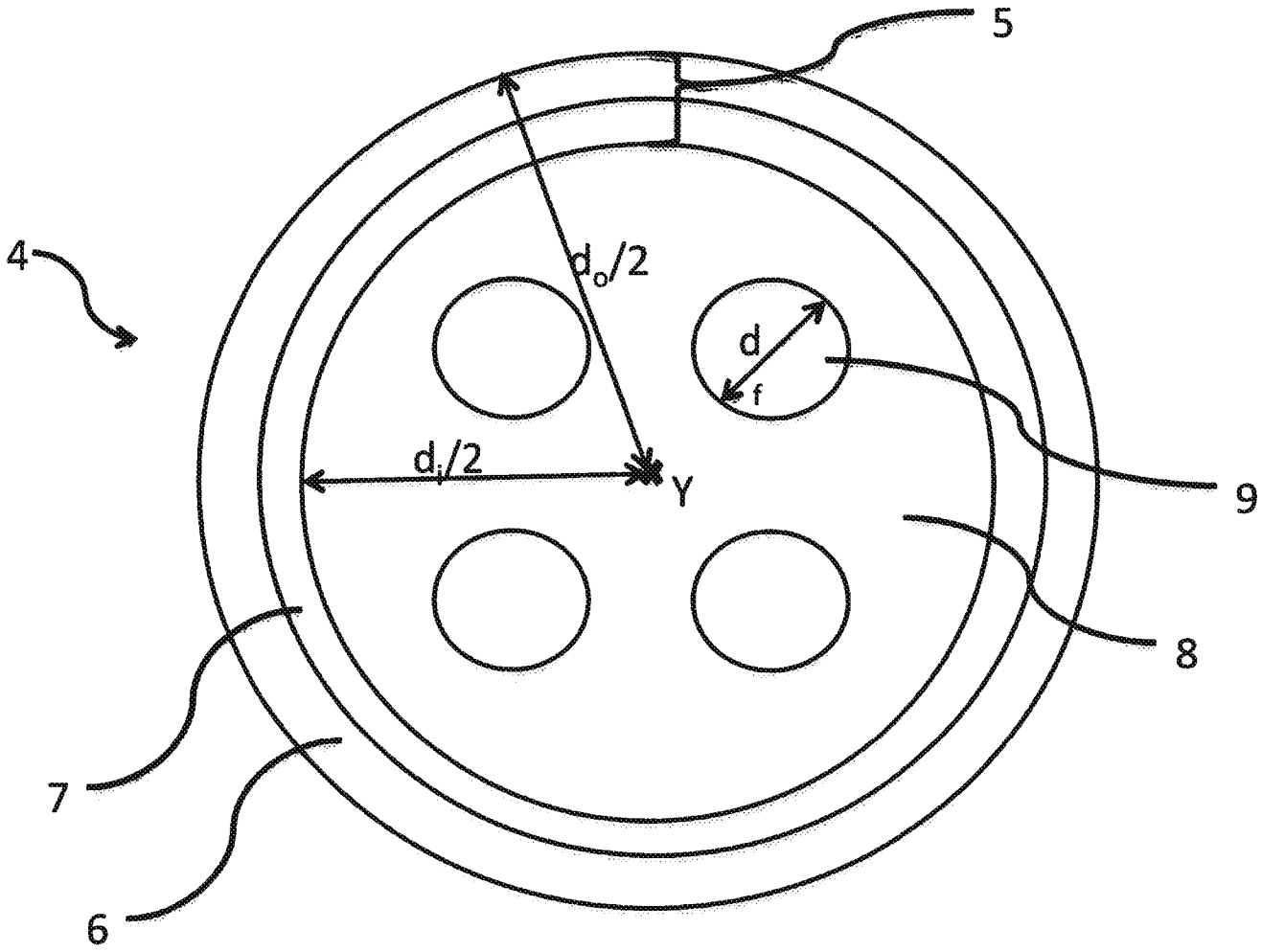


Figure 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/002207

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B6/44 G02B6/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	WO 2004/081611 A2 (DU PONT [US]; BOOGH SONIA JAPON [CH]) 23 September 2004 (2004-09-23) page 4, line 34 - line 37 page 9, line 1 - page 10, line 28	1-15
Y	WO 2007/091880 A1 (DRAKA COMTEQ BV [NL]; WEISS ALEXANDER [DE]; NOTHOFER KLAUS [DE]; LAUSC) 16 August 2007 (2007-08-16) page 3, line 31 - line 33	11

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

[X] See patent family annex.

* Special categories of cited documents :

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 May 2015	21/05/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Frisch, Anna Maria

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/002207

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 2 312 359 A1 (DRAKA COMTEQ BV [NL]) 20 April 2011 (2011-04-20) abstract; tables 1,2 -----	3,4,9

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2014/002207

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