propagation of higher optical powers free from issues such as nonlinear and thermo-optic effects that can affect optical waves travelling in solid material. However, their incompatibility with conventional testing methods is a significant obstacle to developing this application; testing the quality of installation and longer terms checks of the integrity and performance quality of hollow core optical fibres installed in the field is challenging. Therefore, approaches to enable the testing of hollow core optical fibres and cables including hollow core optical fibres, including testing during installation and for subsequent maintenance, are of interest.

SUMMARY

Aspects and embodiments are set out in the appended claims.

According to an aspect, the present disclosure refers to an optical fibre cable including at least one optical fibre assembly, the at least one optical fibre assembly comprising: a hollow core optical waveguide comprising a hollow core surrounded by a structured arrangement of longitudinally extending capillaries providing an inner cladding surrounded by an outer cladding; a diagnostic solid core optical waveguide comprising a solid core surrounded by a cladding, and extending substantially parallel to the hollow core optical waveguide; and a jacket surrounding both the hollow core optical waveguide and the solid core optical waveguide and forming a common mechanical environment for the hollow core optical waveguide and the solid core optical waveguide.

According to another aspect, the present disclosure refers to a method of testing a hollow core optical waveguide, the method comprising: providing the hollow core optical waveguide in an optical fibre assembly included in an optical fibre cable according to the above aspect; launching one or more test light signals into the solid core optical waveguide of the optical fibre assembly; detecting a portion of the test light signals emitted from the solid core optical waveguide proximate one or both ends of the optical fibre assembly; analysing the detected portion of the test light signal to determine a state of the solid core optical waveguide; deducing a state of the hollow core optical waveguide of the optical fibre assembly from the determined state of the solid core optical waveguide; and designating the optical fibre assembly as operable or inoperable according to the deduced state of the hollow core optical waveguide.

According to a first example, there is provided an optical fibre assembly comprising: a hollow core optical waveguide comprising a hollow core surrounded by a structured arrangement of longitudinally

extending capillaries providing an inner cladding surrounded by an outer cladding; a diagnostic solid core optical waveguide comprising a solid core surrounded by a cladding, and extending substantially parallel to the hollow core waveguide; and a jacket surrounding both the hollow core optical waveguide and the solid core optical waveguide and forming a common mechanical environment for the hollow core optical waveguide and the solid core optical waveguide.

According to a second example, there is provided an optical fibre cable comprising or including at least one optical fibre assembly according to the first aspect.

According to a third example, there is provided a method of testing a hollow core optical waveguide, the method comprising: providing the hollow core optical waveguide in an optical fibre assembly according to the first aspect; launching one or more test light signals into the solid core optical waveguide of the optical fibre assembly; detecting a portion of the test light signals emitted from the solid core optical waveguide proximate one or both ends of the optical fibre assembly; analysing the detected portion of the test light signal to determine a state of the solid core optical waveguide; deducing a state of the hollow core optical waveguide of the optical fibre assembly from the determined state of the solid core waveguide; and designating the optical fibre assembly as operable or inoperable according to the deduced state of the hollow core optical waveguide.

These and further aspects of certain embodiments are set out in the appended independent and dependent claims. It will be appreciated that features of the dependent

CLAIMS

1. An optical fibre cable including at least one optical fibre assembly, the at least one optical fibre assembly comprising:

a hollow core optical waveguide comprising a hollow core surrounded by a structured arrangement of longitudinally extending capillaries providing an inner cladding surrounded by an outer cladding;

a diagnostic solid core optical waveguide comprising a solid core surrounded by a cladding, and extending substantially parallel to the hollow core optical waveguide; and

a jacket surrounding both the hollow core optical waveguide and the solid core optical waveguide and forming a common mechanical environment for the hollow core optical waveguide and the solid core optical waveguide.

2. An optical fibre cable according to claim 1, in which one or more properties of the hollow core optical waveguide and of the solid core waveguide are matched, the properties comprising: microbending sensitivity, fundamental mode field diameter, outer diameter of the cladding, macrobend loss, background optical attenuation, and temperature sensitivity

3. An optical fibre cable according to claim 1 or claim 2, in which the hollow core optical waveguide is a photonic bandgap waveguide configured to guide light along the hollow core by a photonic bandgap effect, the inner cladding comprising a microstructured regular array of longitudinally extending capillaries.

4. An optical fibre cable according to claim 1 or claim 2, in which the hollow core optical waveguide is an antiresonant waveguide configured to guide light along the hollow core by an antiresonant effect, the inner cladding comprising a ring of longitudinally extending capillaries.

5. An optical fibre cable according to claim 4, in which the hollow core optical waveguide is a nested antiresonant nodeless hollow core waveguide, the inner cladding comprising one or more additional capillaries nested within each longitudinally extending capillary.

6. An optical fibre cable according to any one of claims 1 to 5, in which the solid core of the solid core optical waveguide is embedded in the outer cladding of the hollow core optical waveguide so that the outer cladding acts as the cladding of the solid core optical waveguide, and optionally including one or more additional solid cores embedded in the outer cladding to provide one or more additional solid core optical waveguides.

7. An optical fibre cable according to any one of claims 1 to 5, in which the hollow core optical waveguide is located within the solid core optical waveguide, the outer cladding of the hollow core optical waveguide and the core of the solid core optical waveguide being a same layer positioned between the inner cladding of the hollow core optical waveguide and the cladding of the solid core optical waveguide.

8. An optical fibre cable according to any one of claims 1 to 5, in which the hollow core, inner cladding and outer cladding of the hollow core optical waveguide form a first optical fibre strand, and the solid core and cladding of the solid core optical waveguide form a second optical fibre strand distinct from the first optical fibre strand, and the jacket is a coating surrounding the first optical fibre strand and the second optical fibre strand.

9. An optical fibre cable according any one of claims 1 to 5, in which the hollow core, inner cladding and outer cladding of the hollow core optical waveguide form a first optical fibre strand which has a coating layer, and the solid core and cladding of the solid core waveguide form a second optical fibre strand which has a coating layer and is distinct from the first optical fibre strand, and the jacket is a layer of material surrounding the first coated optical fibre strand and the second coated optical fibre strand.

10. An optical fibre cable according to claim 9, in which the optical fibre assembly further comprises additional first coated optical fibre strands and/or second coated optical fibre strands, the first and second coated optical fibre strands arranged in one or more rows such that when the coated optical fibre strands are surrounding by the jacket, the optical fibre assembly forms an optical fibre ribbon.

11. An optical fibre cable according to any one of claims 1 to 5, in which the hollow core, inner cladding and outer cladding of the hollow core optical waveguide form a first optical fibre strand which has a coating layer, and the solid core and cladding of the solid core optical waveguide form a second optical fibre strand which has a coating layer and is distinct from the first optical fibre strand, the optical fibre assembly further comprises an inner buffer layer surrounding the coated optical fibre strands, and the jacket is an outer buffer layer surrounding the inner buffer layer.

12. An optical fibre cable according to any one of claims 1 to 5, in which the hollow core, inner cladding and outer cladding of the hollow core optical waveguide form a first optical fibre strand which has a coating layer, and the solid core and cladding of the solid core optical waveguide form a second optical fibre strand which has a coating layer and is distinct from

the first optical fibre strand, the jacket comprises a hollow tube surrounding the first coated optical fibre strand and the second coated optical fibre strand, and the optical fibre assembly further comprises a filler material occupying space between the coated fibre strands and the hollow tube.

13. An optical fibre cable according to any one of claims 1 to 5, in which the hollow core, inner cladding and outer cladding of the hollow core optical waveguide form a first optical fibre strand which has a coating layer, and the solid core and cladding of the solid core optical waveguide form a second optical fibre strand which has a coating layer, the optical fibre assembly further comprising a hollow tube containing each coated fibre strand and filler material in each hollow tube around the coated fibre strands, and the jacket comprises material surrounding each hollow tube.

14. An optical fibre cable according to any preceding claim, in which the optical fibre assembly further comprises an elongate strengthener extending substantially parallel to the hollow core optical waveguide and the solid core optical waveguide and surrounded by the jacket.

15. An optical fibre cable according to any preceding claim, in which the optical fibre assembly further comprises at least one additional hollow core optical waveguide.

16. An optical fibre cable according to any preceding claim, in which the optical fibre assembly further comprises at least one additional solid core optical waveguide.

17. A method of testing a hollow core optical waveguide, the method comprising:

providing the hollow core optical waveguide in an optical fibre assembly included in an optical fibre cable according to any one of claims 1 to 16;

launching one or more test light signals into the solid core optical waveguide of the optical fibre assembly;

detecting a portion of the test light signals emitted from the solid core optical waveguide proximate one or both ends of the optical fibre assembly;

analysing the detected portion of the test light signal to determine a state of the solid core optical waveguide;

deducing a state of the hollow core optical waveguide of the optical fibre assembly from the determined state of the solid core optical waveguide; and

designating the optical fibre assembly as operable or inoperable according to the deduced state of the hollow core optical waveguide.

18. A method according to claim 17, further comprising deploying the optical fibre cable as an optical signal transmission pathway before or during the launching of the one or more test light signals.

19. A method according to claim 17 or claim 18, in which the launching, detecting and analysing is in accordance with a visual fibre tracer technique, a visual fault locator technique, an optical time domain reflectometry technique or an optical frequency domain reflectometry technique for testing optical fibres.

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