Research Advances Rapidly on a New Breed of Optical Fiber that Could Lead to Ultrahigh-capacity Communications and Cost Reductions

NTT has made giant leaps forward in research on applying a new type of optical fiber called "holey fiber" [1] that is attracting attention as the next generation of transmission medium and photonic devices. While conventional optical fiber is composed of a solid core surrounded by a cladding, the cladding of holey fiber contains longitudinal air holes arranged like a crystal lattice (**Fig. 1**). By appropriately designing the size, number, and separation of the holes, we have made holey fiber with many optical characteristics impossible with conventional single-mode fiber such as single-mode transmission of an extremely wide range of wavelengths, a dramatic reduction in bending loss, and high polarization maintenance. The pronounced reduction in bending loss makes holey fiber much easier to handle than conventional single-mode fiber, which does not transmit light when it is bent. This can eliminate the need for special cable-laying procedures and permit more versatile laying and installation.

Now that the broadband era is well and truly upon us, and fiber optic services exemplified by B-FLET'S

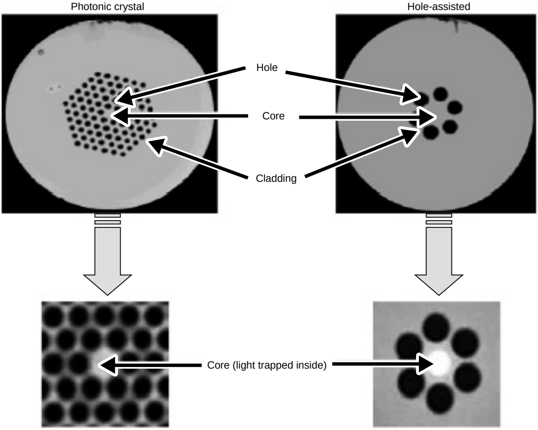

Fig. 1. Holey fiber cross-section.

are showing rapid growth, holey fiber is expected to lead to fast, low-cost fiber optic services for customers.

Background

Optical fiber is widely used, not only in the backbone network but also in access networks. However, the optical characteristics of conventional optical fiber, in which dopants are used to form a waveguide in silica glass, limit potential increases in optical transmissions capacity at currently used wavelengths. Bending loss, connection loss, and other problems, which contribute to optical fiber's reputation of being hard to handle when being laid, are also issues.

To create a more economical network by greatly increasing the backbone capacity, NTT has conducted research and development of holey fiber, which has excellent transmission and bending loss characteristics. This research has produced many pioneering results. One example is the steady reductions in loss that have been achieved with photonic crystal optical fiber, which contains dozens of holes. In March 2003, NTT Access Network Service Systems Laboratories set a world record for low loss levels (0.37 dB/km) and six months later in September broke its own record (0.28 dB/km). In pushing the boundaries of intrinsic loss in silica fiber (theoretical limit: 0.14 dB/km), NTT is conducting research and development aimed at introducing holey fiber in the future.

Hole-assisted optical fiber, which has several holes, not only reduces bending loss but also reveals the fundamental structure required to achieve connection loss levels comparable with those of conventional fiber technology.

Characteristics of new-generation optical fiber

Among various types of holey fiber[*1], the photonic crystal fiber, with which NTT recently set the world record for low loss levels, has the following attractive characteristics.

- single-mode transmission[*2] over a very wide range of wavelengths
- major reduction in bending loss (can be effectively zero)
- a variety of dispersion properties[*3]
- flexible control of optical non-linearity[*4]
- high polarization-maintenance[*5]

The wider range of single-mode wavelengths has generated great expectations for superior wavelength division multiplexing (WDM)[*6] in the photonic networks[*7]. We can expect ultrahigh-capacity optical communication using wavelengths ranging from visible to the near infra-red.

The emergence of hole-assisted optical fiber has opened the way to optical fiber that has low bending loss and this has increased the possibility of deploying a high-speed communication infrastructure quickly and at low cost.

Future developments

NTT will continue to study the feasibility of photonic crystal fiber as a future transmission medium by investigating transmission characteristics at various wavelengths and ways of improving transmission performance, as well as establishing testing, connection, and cabling technologies. We are also continuing to investigate alternative structures for bend-resistant optical fiber and will continue research and development with the aim of applying this technology as soon as possible.

Reference

[1] J. C. Knight, T. A. Birks, P. St. J. Russell, and D. M. Atkin, "All-silica single-mode optical fiber with photonic crystal cladding," Opt. Lett. 21 (1547-1549) 1996.

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*1 Holey fiber: Typical examples include hole-assisted fiber (highly refractive core and a few holes), photonic crystal fiber (silica glass core and several dozen holes), and photonic band-gap fiber (hollow core and dozens of holes).

*2 A single-mode optical fiber is more suitable for high-speed transmission than multimode fiber.

*3 Dispersion causes optical pulses with different wavelengths to move at different velocities.

*4 Non-linearity means that the refractive index of the fiber depends on the optical power in the fiber.

*5 Polarization-maintenance: the state of polarization is kept constant along the fiber.

*6 Wavelength division multiplexing (WDM) is a technique in which several optical signals of differing wavelengths are transmitted down the same optical fiber. WDM is attracting attention as a key technology for achieving a photonic network. There has also been much research into dense WDM (DWDM) in recent years.

*7 Photonic network: The next-generation networks are expected to be based on optical technology, which is more suitable for high-speed, high-capacity communication than electrical technology. Optical components are used and high speed is achieved by communicating using only light signals, without any conversion to electrical signals.