The operating principle behind hollow-core photonic bandgap fibers is very different from that of conventional fibers that guide light by total internal reflection; they are related more to that of a multi-layer mirror. For certain incident angles and optical frequencies, the reflection from each layer of holes can add up coherently, transforming the dielectric cladding into an almost perfect two-dimensional mirror, which keeps the light in the core of the fiber.

**Key Properties**
- Available in a Wide Range of Design Wavelengths
- Available with 7-Cell and 19-Cell Cores
- Operating Bandwidth is ±10% of Design Wavelength
- Attenuation from 20 dB/km (1550 nm) to 300 dB/km (830 nm)
- Zero Dispersion Occurs at a Wavelength in the Operating Band
- Near-Gaussian Fundamental Mode
- Virtually Free of Optical Nonlinearity
- Virtually Immune to Bend Loss
- No Fresnel Reflection from the Endfaces (Modal Index=1)

**Optical Properties**
- **Modal Properties**
  As with conventional single mode fibers, the favored mode in hollow-core PFC has a quasi-Gaussian intensity distribution. In the case of the 19-cell hollow-core fiber with a 1550 nm operating wavelength (HC19-1550), the measured shape overlap with the fundamental mode of an all-solid step-index fiber is >97%, facilitating coupling to high-mode-quality lasers or conventional fiber. Even though hollow-core PCFs are intended to be used like other single mode fibers, no low-loss, hollow-core PCF demonstrated to date is a true single mode waveguide; typically, they support several higher order core modes, and in some cases, they support additional surface modes located at the core/cladding boundary. All of these modes have higher loss than the fundamental mode and generally decay rapidly, but their presence needs to be taken into account when designing input and output coupling optics.

**Chromatic Dispersion**
Unlike in conventional fiber where material dispersion plays a major role, Group-Velocity Dispersion (GVD) in hollow-core PCF is dominated by waveguide dispersion. For any design wavelength, including those where the dispersion of silica makes it impossible to achieve zero dispersion in conventional fiber, dispersion is upward sloping and crosses zero at a wavelength close to the center of the operating wavelength band (see box on the next page).

**Attenuation**
Hollow core fibers only guide over a wavelength range covered by the photonic bandgap in the cladding. Outside this range (typically about ±10% of the design wavelength) loss increases sharply.

**Applications**
- Delivery of Ultra-Short High-Power Optical Pulses
- Pulse Compression and Pulse Shaping
- Sensors and Spectroscopy
Hollow-Core, Photonic Crystal Fibers (Page 2 of 3)

Application Example – Delivery of Femtosecond Pulses from a Ti:Sapphire Laser

Since most of the optical power is located in the core and cladding holes and not in the glass, the nonlinearity of hollow-core fibers can be 2 to 3 orders of magnitude smaller than that of conventional fibers. These characteristics, along with the fact that dispersion crosses zero within the operating waveband, make these fibers ideally suited for the delivery of ultra-short, high-power optical pulses.

This is demonstrated here for the delivery of 150 fs, 8 nJ pulses from a Ti:Sapphire laser over a 1.5 m long fiber. Around the zero dispersion wavelength, the pulses leave the fiber virtually undistorted, despite the fact that the peak power exceeds 100 kW.

Low nonlinearity and anomalous dispersion at any wavelength also make it possible to transmit more powerful pulses in a soliton regime.* ** Peak powers of up to 2 mW have been transmitted without causing damage to the fiber.

* Ouzounov et al., Science, 301, 2003
** Luan et al., Opt. Express, 12, 2004

7- and 19-Cell Cores

Core Size:
Hollow core fibers are available in two core sizes, which are optimized for different application requirements.

7-Cell Core
- Larger Continuous Operating Bandwidth
- Smaller Number of Core Modes and Parasitic Surface Modes

19-Cell Core
- Larger Mode Field Diameter
- Lower M² of Fundamental Mode (More Gaussian-Like), Resulting in Increased Coupling Efficiency to High-Mode-Quality Lasers and Conventional Fibers
- Lower Attenuation
- Lower Dispersion and Dispersion Slope
- Lower Optical Nonlinearity
- Higher Breakdown Power Threshold

The graph above compares typical transmission spectra for a 7-cell (HC-1550) and a 19-cell core fiber (HC19-1550), both designed for operation at 1550 nm. The peaks in the transmission band of the 19-cell fiber are due to surface modes that have a propagation constant that is degenerate with the fundamental mode at certain wavelengths.
Hollow Core Photonic Crystal Fibers (Page 3 of 3)

Hollow Cores

Photonic bandgap (hollow-core) fibers guide light in a hollow core that is surrounded by a microstructured cladding formed by a periodic arrangement of air holes in silica. Since only a small fraction of the light propagates in glass, the effect of material nonlinearities is significantly reduced, and the fibers do not suffer from the same loss limitations as conventional fibers made from solid material alone. The fiber is protected by a single-layer acrylate coating and can be stripped and cleaved like ordinary solid fibers.

HC-1550

<table>
<thead>
<tr>
<th>ITEM#</th>
<th>CENTER λ, (nm)</th>
<th>CORE DIA, (µm)</th>
<th>MFD, (µm)</th>
<th>NUMERICAL APERTURE</th>
<th>EFFECTIVE MODE INDEX</th>
<th>ATTENUATION, (dB/km)</th>
<th>BANDWIDTH, (nm)</th>
<th>CLADDING DIA, (µm)</th>
<th>COATING DIA, (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC-1550</td>
<td>1590</td>
<td>10.9</td>
<td>7.5</td>
<td>-0.2</td>
<td>-0.99</td>
<td>&lt;30</td>
<td>1490 - 1690</td>
<td>120</td>
<td>220</td>
</tr>
<tr>
<td>HC19-1550</td>
<td>1570</td>
<td>20 ± 2</td>
<td>13</td>
<td>-0.13 ± 0.03</td>
<td>-0.995</td>
<td>&lt;20</td>
<td>1530 - 1610</td>
<td>115</td>
<td>220</td>
</tr>
<tr>
<td>HC-1060</td>
<td>1060</td>
<td>9.7</td>
<td>6.5</td>
<td>-0.2</td>
<td>-0.99</td>
<td>&lt;100</td>
<td>1015 - 1105</td>
<td>125</td>
<td>220</td>
</tr>
<tr>
<td>HC-800</td>
<td>830</td>
<td>9.2**</td>
<td>8.8</td>
<td>-0.2</td>
<td>-0.99</td>
<td>&lt;300</td>
<td>780 - 870</td>
<td>135</td>
<td>220</td>
</tr>
</tbody>
</table>

*Full 1/e² width of the near field intensity distribution.
** 9.2 µm for long axis, 9.5 µm for short axis.

## Laser Diodes

- 5.6 mm and 9 mm Packages
- Wavelengths from 405 nm to 1550 nm
- Output Powers Up to 1 W
- Variety of Standard Pin Configurations

See Page 1032

## Benchtop Current Controller

- Drive Currents from 20 mA to 4 A Available
- Compatible with All Laser Diode Polarities
- Constant Current and Constant Power Modes

See Page 1176