From photonics.com - 7/1/2007
http://www.photonics.com//content/spectra/2007/July/research/88170.aspx

Multicore Fiber Amplifier Is an Image Intensifier

Each of 19 cores intensifies one pixel of the image.

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Image intensifiers have many applications — from biomedical imaging to optical metrology — and are especially important to the military, where they enable nighttime maneuvers that would be impossible otherwise. Conventional image intensifiers rely on the principle of electron multipliers: Weak incoming light excites a few electrons from a photocathode that are subsequently amplified in a high-voltage cascade and that eventually impinge on a phosphor.

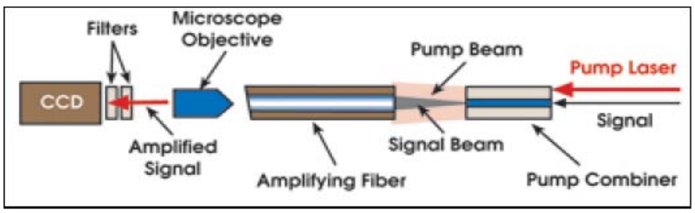

Figure 1. *The image — in this case a Gaussian intensity profile from an amplified spontaneous emission source — illuminated the input end (right) of the multicore, double-clad fiber. A microscope objective on the output side of the fiber focused the intensified image through neutral-density filters onto a CCD camera. Images reprinted with permission of Optics Express.*

Although this technology has proved immensely useful, it has several drawbacks. Its response time can be relatively slow, and much of the optical information in the original signal — polarization, spectral content, coherence — is lost.

To overcome these drawbacks, scientists at NP Photonics Inc. in Tucson, Ariz., designed and demonstrated an image intensifier that amplifies photons directly in a multicore optical fiber. Each of the fiber's 19 cores amplifies a single pixel of the image, so that, at present, only 19 pixels of an image can be amplified. The scientists are working on increasing the number of cores and, hence, the number of pixels that can be amplified. A 12 × 12 image amplifier, containing 144 pixels, has been fabricated and is currently undergoing testing.

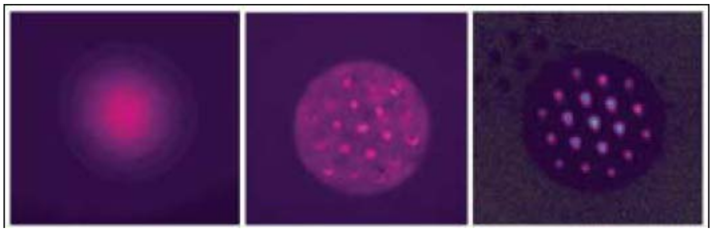

Figure 2. *The photo on the left shows the amplified spontaneous emission intensity profile imaged on the input facet of the fiber image intensifier. The middle and right photos show, respectively, the output intensity with and without gain in the intensifier. Neutral-density filters (necessary to protect the CCD camera) prevent the ~20-dB gain in the photo on the right from being visibly obvious. Significantly, however, the intensity profile of the amplified image (right) was identical to that of the unamplified image (middle).*

Although multicore fibers previously were evaluated as image intensifiers — sometimes with as many as 3000 cores — their gain was limited because they were fabricated with silica glass. Phosphate glasses, which were used by the NP Photonics scientists, can accept erbium or ytterbium doping levels 50 to 100 times higher than silica fibers and thus yield much more gain from shorter fibers. In this case, the scientists saw as much as a 30-dB gain in each of the 19 cores of their 10-cm-long, double-clad fiber when they pumped it with 3 W at 975 nm. The double-clad-fiber design is utilized to confine pump light from high-power multimode diode lasers and to efficiently energize the cores uniformly.

The scientists believe that even higher gains could be achieved simply. The facets of the fiber were cleaved normal to the cores so that, when the gain reached 30 dB, the fiber began lasing, and the gain saturated. It would be a simple matter to cleave the facets obliquely, raising the laser threshold — and the achievable gain — significantly.

The scientists did just that to evaluate the fiber as an image intensifier. They cleaved the output end of the fiber at ～13° and illuminated the input end of the fiber with a nearly Gaussian profile from an amplified-spontaneous-emission source (Figure 1). The increased visibility of the intensified image is not immediately obvious from the results shown in Figure 2 because the scientists inserted neutral-density filters to protect the CCD camera from the higher intensity. However, the measured net gain of the intensifier in these photographs was ～20 dB, and the intensity distribution of the amplified image was proportional to that of the input image.

Because the fiber image intensifier amplifies photons directly, without converting them to electrons, the optical information in the incoming image is preserved through the amplification process. Moreover, because this intensifier is at its heart simply an erbium-doped fiber amplifier — which canoperate at 40 GHz and higher — this image intensifier is capable of frame rates much greater than those of the typical electron-multiplier intensifier. In this particular demonstration, the frame rate was limited by the readout time of the CCD camera.

Although the scientists designed this demonstration in the strong gain band of ytterbium at ～1020 to 1070 nm, they point out that other rare-earth-doped fibers could extend the operation range of fiber-based image intensifiers from the visible up to wavelengths as long as 2 µm.

Optics Express, April 2, 2007, pp. 3759-3765.