Silica based erbium doped fiber extending the L-band to 1620+ nm

Inger Pihl Byriel (1), Bera Pálsdóttir (1), Matt Andrejco (2), C.Christian Larsen (1)

(1) Lucent Technologies Denmark, ibyriel@lucent.com
(2) Specialty Fiber Devices, Lucent Technologies, Somerset, NJ, USA

Abstract: A fiber has been developed for use in extended L-band amplifiers, utilizing the wavelength range from 1565 to 1620 nm. The fiber is silica based and has low splice loss to standard telecommunication fiber. The quantum conversion efficiency is >60%.

Introduction

Research and development in the field of optical communications is focused on increasing the capacity. Bit rate and bandwidth are being increased. Current Er-doped fiber (EDF) amplifier based systems operate in the wavelength ranges from 1530 – 1565 nm (C-band) and 1565 – 1605nm (L-band). Activities to broaden this range concentrate on Raman gain /1,2/ Tm and Pr doped fluoride glasses /3/ and multicomponent antimony silicate glasses /4/. The latter two approaches have the disadvantage that the glass host used can not be fusion spliced to standard telecom fibers, and they suffer in many cases from high background loss, low power conversion efficiency and problems with reliability.

In this paper, it is for the first time shown that it is possible to change the optical gain spectrum in the L-band of an Er-doped fiber based on a silica host glass. By varying the co-dopants and their concentrations in erbium doped fibers, the strength of transitions between energy levels, and their energy separation can be altered. The gain bandwidth of EDF's in the L-band can be extended to longer wavelengths by shifting an excited state absorption (ESA) of the L-band signal to longer wavelengths.

In this paper we present a silica based EDF, with a broad gain bandwidth from 1565 to 1620 nm, extending the bandwidth by 20% or more.

Gain spectrum

Three new fibers, A, B, and C, have been measured in an L-band amplifier. The amplifier configuration is shown in Figure 1. 10 L-band channels of equal power were launched into the fiber while co-pumping at 980 nm and counter-pumping at 1480 nm. The 8 channels in the middle were fixed during the measurements whereas the outer channels were stepped to lower and higher wavelengths, respectively, to investigate the extend of the gain band. The total signal input power was approximately -4 dBm for fibers A and C, and +3 dBm for fiber B and the conventional fiber (the fibers in figure 2). The pump powers were 110 mW at 980 nm for the co-pump and the 1480 nm counter-pump was varied between 143 and 173 mW to optimize the inversion level.

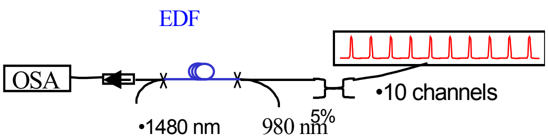

Figure 1 L-band amplifier configuration.

The presented gain curves are for erbium fiber only, i.e. the results are corrected for splice loss and loss of passive components in the amplifier.

The gain spectrum for the new fiber B is shown in Figure 2. For comparison a gain spectrum for a conventional Al/La doped silica L-band fiber is shown as well.

The gain flatness of the new fiber is limited by the dip at 1580 nm. Defining the gain ripple as Gr = (Gmax-Gmin)/Gmin, the new fiber has a 25% gain ripple over 59 nm, from 1563 nm to 1622 nm. The bandwidth of the conventional fiber is 49 nm for the same gain ripple, from 1564 – 1613 nm

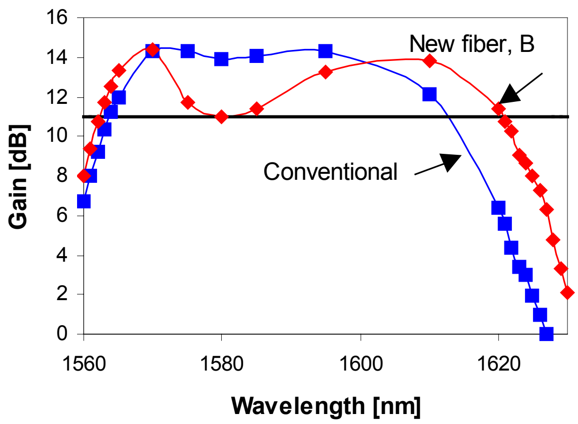

Figure 2. Measured gain curves for fiber B and a conventional L-band EDF.

Figure 3 shows gain spectra for three of the new fibers. The difference in spectral shape is caused by difference in dopant concentration. The difference in gain level is primarily caused by difference in conversion efficiency. The conversion efficiency (see Table 1) is limited by background attenuation and clustering of erbium ions. The clustering varies with host glass, erbium concentration and manufacturing conditions. Conversion efficiency can still be optimized further for this glass host.

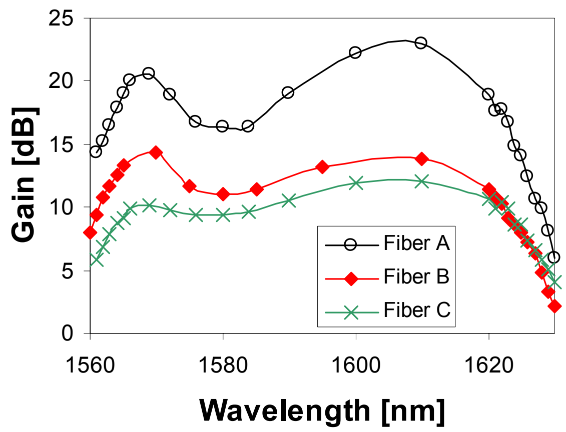

Figure 3. Measured gain spectra for fibers A, B and C. Fiber A is 130 m, fiber B is 20 m and fiber C is 7 m.

Fiber characteristics

The optical and physical properties of the new fibers have been investigated. Peak absorption around 1530 nm, background loss at 1200 nm, mode field diameter (MFD), cut-off wavelength, numerical aperture, and quantum conversion efficiency (QCE) for the fibers A, B, and C are summarized in Table 1.

Table 1 Optical parameters for the fibers A, B, and C

Fiber:	A	B	C
Peak absorption @ 1530 nm	11	26	70
Loss @ 1200 nm (dB/km)	18	17	25
MFD @1550 nm (µm)	6.5	6.0	8.5
Cut-off wavelength (nm)	820	1000	1620
Numerical aperture	0.23	0.22	0.13
QCE	0.66	0.36	0.32

The L-band amplifier used in this work is far from saturation, and QCE thereby strongly dependent on operating conditions and amount of ASE in the C-band. To compare the degree of clustering between the fibers, QCE is measured in a saturated C-band amplifier. The signal input is 0 dBm at 1550 nm and the pump power is 150 mW at 980 nm, co-propagating. QCE of these fibers is 0.32 – 0.66. For comparison, QCE (using the same configuration) is about 0.80 for conventional C-band fibers and 0. 70 – 0.80 for conventional L-band fibers, depending on erbium concentration.

All the new fibers fulfil the physical specifications of standard transmission fiber i.e. cladding diameter is 125 ± 1 µm, core eccentricity is < 0.5 µm, the diameter of the dual layer acrylate coating is 245 ± 10 µm, and the fibers are prooftested at 2%.

The strength of the new fiber was tested according to a Telecordia procedure. A Weibull plot, showing the probablility for a fiber break as a function of applied stress, is displayed in Figure 4. The new fiber is shown and compared to a conventional fiber. The curves for both fibers are almost identical and for the new fiber the Weibull slope and the median tensile strength was found to be 132 and 5.30 GPa, respectively.

This show that the strength of this new EDF is the same as for standard transmission fiber.

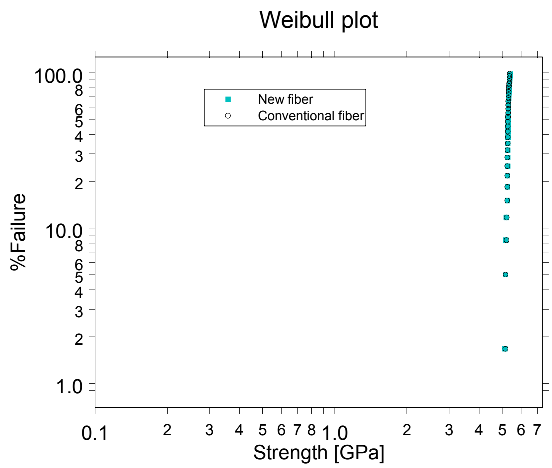

Figure 4. Dynamic tensile strength of a new fiber and a conventional fiber.

As the fiber is silica based it can be fusion spliced to standard transmission fibers. The splice loss has been optimized to 0.15 dB at 1550 nm. The wavelength dependence of the splice loss is very small, the loss at 1610 nm is 0.16 dB.

Conclusion

We have shown that the gain bandwidth can be increased by 20% or more in the L-band, to above 1620 nm in co-doped silica Erbium-fibers.

Fibers with these properties, and with the same mechanical and optical properties as standard telecom fibers have been manufactured.

The conversion efficiency is comparable to standard L-band fibers, and the splicing performance is good.

References

/1/ J. Bromage et al. OFC´01 Paper PD4.

/2/ B.B. Puc et al. OFC'01 Paper PD39.

/3/ A. Mori, ECOC'99, PaperTuD3.1, p I 261.

/4/ A.J.G. Ellison et al. OFC´01(2001), Paper TuA2.