# LF 3000 series ASE erbium fibers

Liekki has developed a new line of highly erbium-doped fibers for amplified spontaneous emission (ASE) sources. LF 3000 series fibers give customers the ability to enhance or expand their product offering and address end users needs better by improved light intensity and spectral characteristics.

ASE sources are becoming standard commodity of optical telecommunication and fiber optic sensor industries. They provide incoherent, stable and high spectral density light for characterizing fiber-optic components, fiber optic stress and strain sensors and biomedical sensing. Erbium fiber ASE sources are popular because they offer one hundred times (20 dB) stronger light than an LED, and up to 100,000 (50 dB) times stronger light than a white light tungsten lamp source. Furthermore, ASE sources are compatible with fiber optic components and are now available at a cost that is very competitive with existing alternatives. A key problem in many ASE sources is spectral ripple in the power spectral density.

There are both intrinsic and extrinsic methods to equalize the spectrum ripple. Intrinsic methods consist of modifying the spectroscopic properties of erbium ions by a change in co-doping ions or glass matrix. Alumina-silicate glasses are such host matrixes that improve the flatness of ASE spectra. However, intrinsically equalized ASE sources are accurate only to certain extent. Better accuracy is achieved using extrinsic methods by applying a filtering device connected in series with the erbium-doped fiber. Filters that could be utilized in ASE sources include Bragg gratings and blazed gratings. Bragg gratings shape the ASE spectrum accurately, but they can drift with temperature and make the shaped ASE source application specific. Novel switched blazed gratings based on MEMS mirror arrays enable dynamic control of the spectrum and allow users to adjust virtually any source spectrum shape. In many case the source performance benefits from intrinsic equalization, since optical power lost in filtering is minimized. Additionally, the inherently flat spectrum can be easier smoothed across the required wavelength band with improved accuracy.

Liekki DND is a very versatile process for specialty fiber production. In the DND process, erbium ions are introduced into the preform deposition layers along with the other constituent materials. In standard production processes one of the major problems is that $Er^{3+}$ ions tend to cluster in the glass matrix, leading interactions between adjacent ions and various nonradiative decay processes. The clustering problem has been eliminated completely through DND process that enables improved solubility of individual erbium ions and their incorporation into the glass host in a uniform distribution of high density.

Liekki offers three types of fiber with different erbium concentration for ASE source applications. The optimum concentration and cut off wavelength depends on pumping scheme and the target specifications of the ASE source. LF 3200 low concentration fiber is designed for applications where conversion efficiency is the most important single parameter our LF 3400 high concentration fiber minimizes the required fiber length. LF3300 is a compromise in between these two extremes providing good conversion efficiency and short fiber length.

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## Measurement results

We characterized the LF 3400 (absorption 44 dB/m at 1530 nm) fiber in our test set-up illustrated in figure 1. The configuration was left without a spectral flattening filter and the pump power was measured at the ends of the pigtail fibers. The coupling and splice losses were

- EDF – SMF 0.2 dB
- SMF – SMF 0.1 dB
- Isolator insertion 0.5 dB
- 980/1550 WDM insertion 0.4 dB for pump and 0.7 dB for signal
- 1480/1550 WDM insertion 0.2 dB for pump and 0.4 dB for signal

Two measurements were conducted with different pump power schemes; in the first case, illustrated in figure 2, the forward pump power is higher than the backward pump power. In the second case, illustrated in figure 3, the backward pump power is higher than the forward pump.

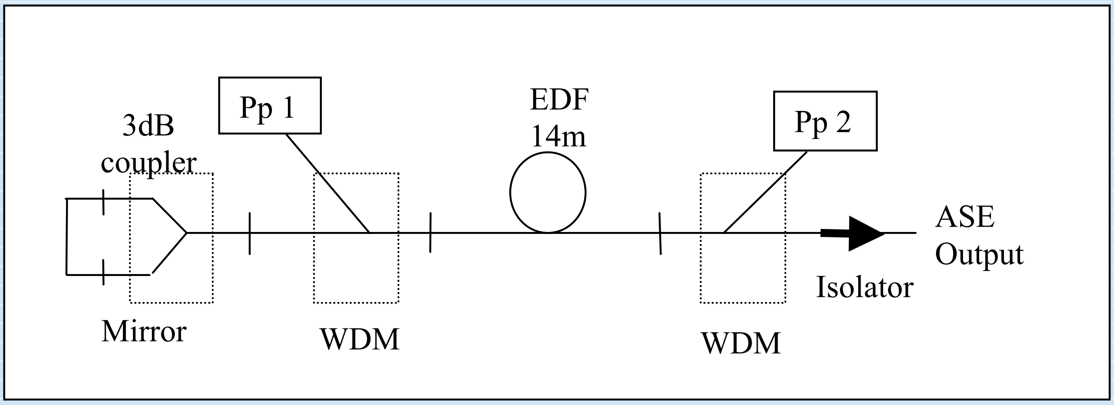


*Figure 1.* Schematic of the measurement set-up

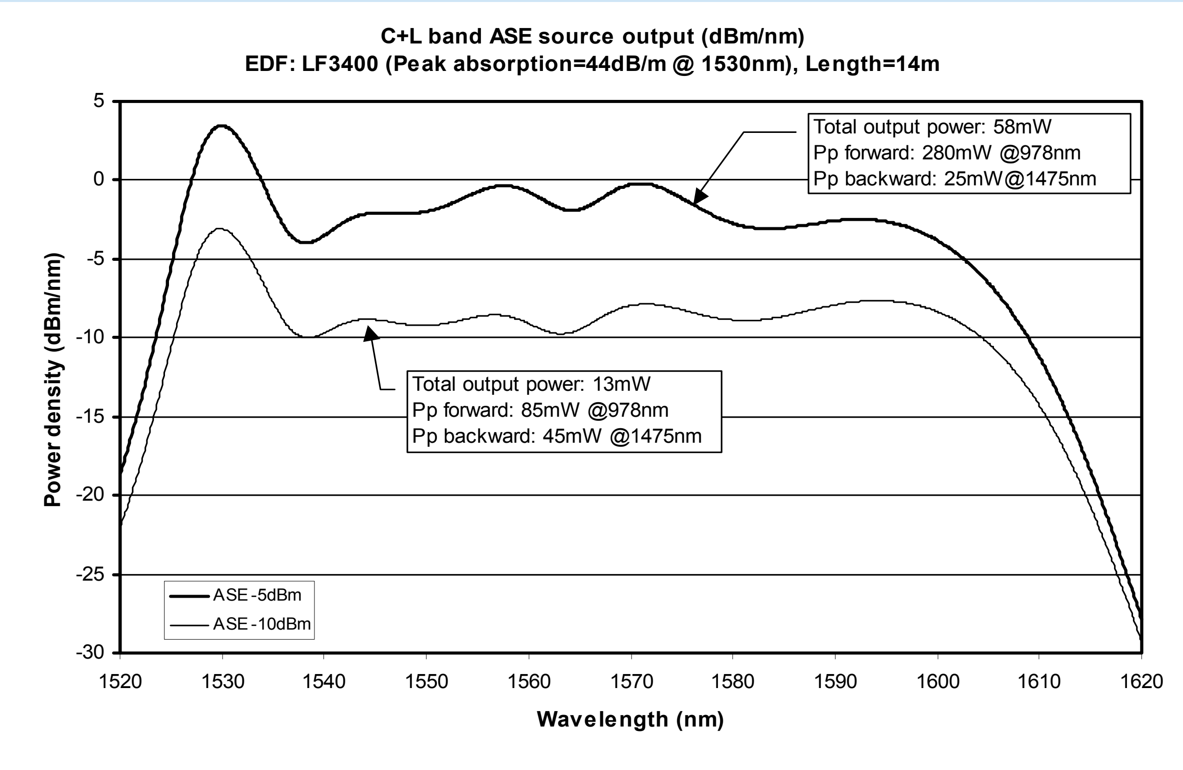


*Figure 2.* The ASE spectrum ripple is less than 7 dB across the 1525 – 1605 nm band.

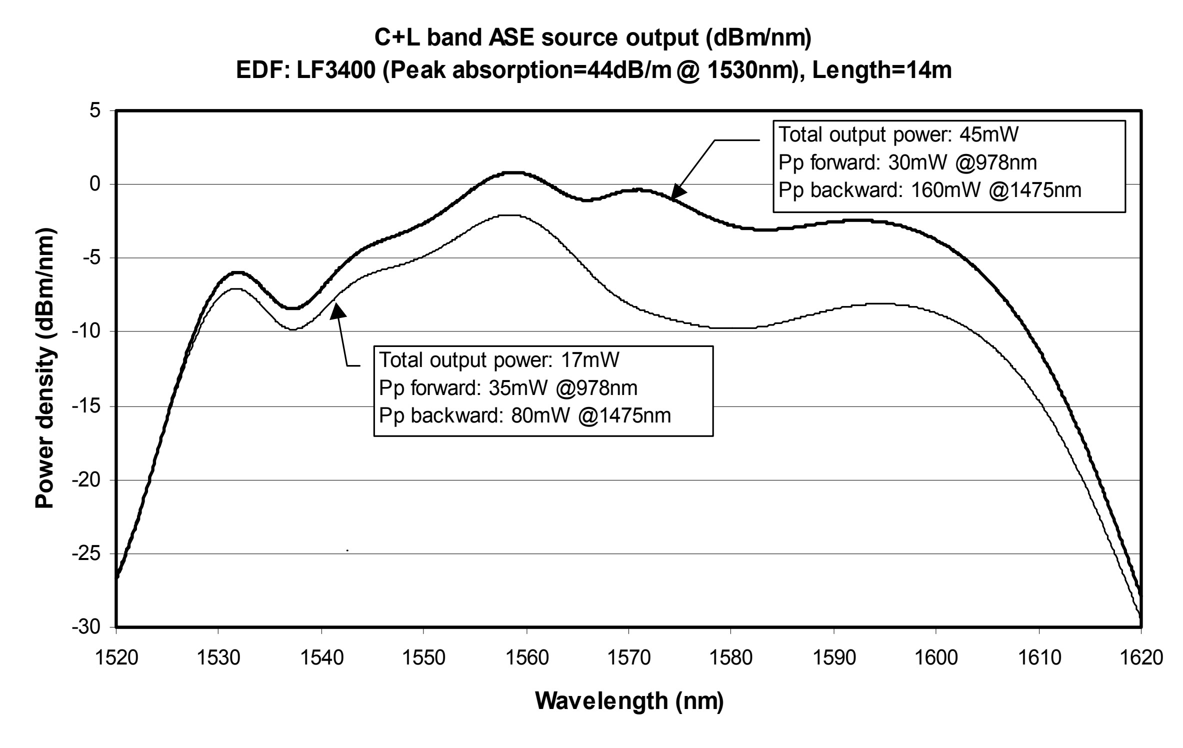


*Figure 3*. The ASE spectrum ripple is low at L-band, but increases at C-band.

## Conclusions

To control the output power spectral density and shape, one should be able to tune both pump powers and doped fiber length. The backward-propagating pump power controls mainly the total output power and spectral power density. The forward propagating pump power rules the balance between C-band range and L-band range output powers. If we consider only the L-band, the fiber length has an effect on spectral ripples. In the first case, we noticed that backward-propagating pump wavelength effects the spectral flattness in the C-band. Additionally, the simulations indicate that by moving pump wavelength from 978nm to 990nm, the 1530nm and 1550nm peaks could become almost equal. Pumping at 990 nm and use of high reflection mirror instead of 3dB coupler would improve the power conversion efficiency. As a conclusion, we achieved 1525-1605 nm bandwidth with output power density better than - 10dBm/nm. The maximum ripple over the band was 7dB without filtering.

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