

1.55- μm Fiber-Optic Amplifier

The fiber-optic amplifier is a key element in modern high-data-rate communications. Its large optical bandwidth, ≈ 4000 gigahertz, makes it effectively transparent to data rate and format changes, allowing system upgrades without modifications to the amplifier itself. The most prevalent fiber-optic amplifier is called the erbium-doped fiber amplifier (EDFA). It provides amplification in the third telecommunications window centered at a wavelength of $1.55 \mu\text{m}$. The EDFA has four essential components, as shown in Fig. 1. These are the laser diode pump, the wavelength division multiplexer (WDM), the erbium-doped optical fiber, and the optical isolators. To achieve optical amplification, it is necessary to excite the erbium ions situated in the fiber core from their ground state to a higher-energy metastable state. A diagram of the relevant erbium ion energy states is shown in Fig. 2. The erbium ions are excited by coupling pump light (≈ 20 mW or greater) through the WDM into the erbium-doped fiber. Commonly used pump wavelengths are 980 nm and 1480 nm. The ions absorb the pump light and are excited to their metastable state. Once the ions are in this state, they return to the ground state either by stimulated emission or, after about 10 ms, through spontaneous emission. Light to be amplified passes through the input isolator and WDM and arrives at the excited erbium ions distributed along the optical fiber core. Stimulated emission occurs, resulting in additional photons that are indistinguishable from the input photons. Thus, amplification is achieved. Optical isolators shield the amplifier from reflections that may cause lasing or the generation of excess amplified spontaneous emissions (ASE).

Good EDFA design typically requires reduction of optical losses at the amplifier input and minimizing optical reflections within the amplifier. EDFAs with greater than 30-dB optical gain, more than 10-mW output power, and less than 5-dB noise figure are readily achieved in practice.

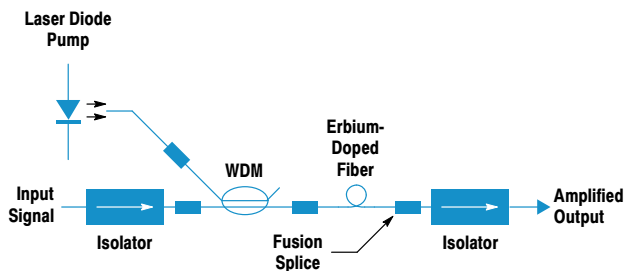


Fig. 1. Schematic of an erbium-doped fiber amplifier showing essential optical components. The WDM is a wavelength division multiplexer.

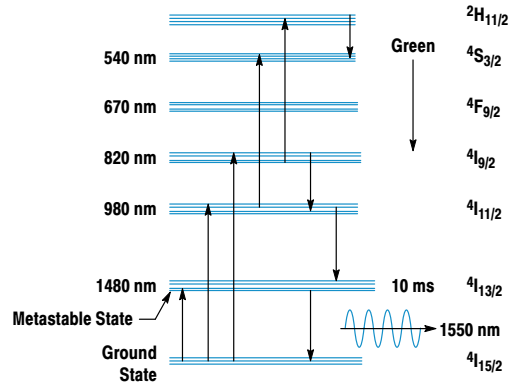


Fig. 2. Relevant erbium ion energy levels.

ASE is generated in optical amplifiers when excited ions spontaneously decay to the ground state. The spontaneously emitted photons, if guided by the optical fiber, will subsequently be amplified (by the excited ions) as they propagate along the fiber. This can result in substantial ASE powers (> 10 mW) at the amplifier output. A typical spectrum of signal and ASE at the amplifier output is shown in Fig. 3. The ASE can extend over a broad spectral range, in this case in excess of 40 nm.

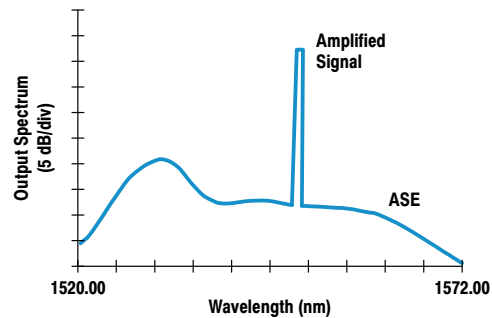


Fig. 3. Spectrum of amplified spontaneous emissions (ASE) and amplified signal at the amplifier output.