Cladding pumped technology

Basic technology

A single scientific discovery often results in hundreds of new products in many industries. Cladding pump technology was such an invention. Elias Snitzer first described cladding pumped lasers in 1988. Light was directed into the cladding of an optical fiber where it could then provide energy to a lasing material in the fiber core. An effective method of getting the light into the cladding was discovered soon afterwards at the IRE Polus company in Moscow by Valentin Gapontsev and Igor Samartsev. Their side-pumping techniques, sketched in figure 1, allowed many laser diodes to pump one single-mode fiber, making high power, infrared lasers with near perfect beam quality. Lasers which once filled a room were now no bigger than a book. Not only did these discoveries result in a variety of fiber lasers but also high power optical amplifiers. Optical amplifiers convert a small light signal into a powerful beam, often a thousand times brighter, but otherwise identical to the original signal. These optical amplifiers are now used in systems ranging from cable television distribution to air-based networks beaming Internet data directly into offices through the nearest window. More recently, several new classes of devices have been invented; amplifiers for different wavelengths of light and others that produce high power, low cost amplification over a wider range of wavelengths.

Broad-area laser diodes provide the light energy to power the fiber laser (or amplifier). These small, rugged and reliable diode light sources are a high power, telecom grade version of the type of laser used in CD players. Although the beam is not round and, for a laser beam, rather large, almost all the

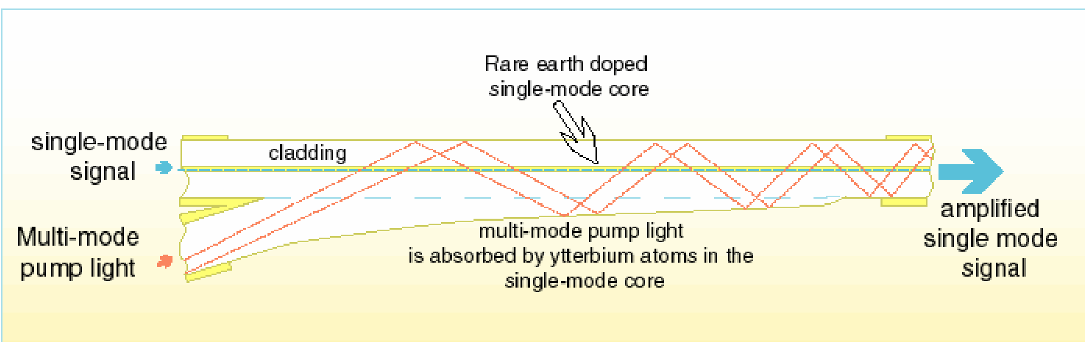


Figure 1. The original side pump technique for transferring energy from a large area laser diode into a small (single mode) fiber core to allow light to be amplified.

light from the laser can be captured by a multimode (large core) fiber. The light is then guided into the inner cladding of a single mode (small core) fiber as drawn in the picture above (Figure 1). Each time the light crosses the single mode core some of the light is absorbed by atoms of ytterbium (one of the rare earth elements). This energy can be used by the rare earth to amplify signals traveling along the core or can be transferred to another rare earth, such as erbium to amplify different wavelengths of light. If more power is required, more diodes are coupled into the fiber.

These amplifying devices can be used either as amplifiers or lasers. If some of the signal is reflected back into the fiber at the two ends then this light is amplified and re-amplified as it travels back and forth and it becomes a laser. Since the process occurs inside an optical fiber, even a long laser can be wound up into a small package.

Lasers for manufacturing

Many industries have found uses for the high power and tiny spot size produced by ytterbium and erbium/ytterbium lasers. Some are used in repairing and modifying computer chips; individual microscopic electrical connections can be removed with a highly focused pulse of light. Helicopter LIDAR (light radar) ranging systems use short, high power optical pulses from these lasers to locate high-tension wires and other obstacles.

Many lasers are used for testing optical components for telecommunications. New optical fiber networks have hundreds of milliwatts of optical power passing through the tiny optical components. High power lasers are needed at a variety of wavelengths to test these components. Multi-watt tunable erbium/ytterbium fiber lasers are ideal for fully testing telecom components before they are deployed into networks where they transmit many thousands of simultaneous phone calls and computer links.

Amplifiers for telecommunications

The first fiber amplifiers used expensive single-mode laser diode pumps, and many still do. However the cost of these low power devices limited optical amplifiers to the core of the telecommunications network. They were simply too expensive to use in sending light signals directly into homes and small businesses. The advent of high power, low cost cladding pump technology opened the door to "fiber to the curb" and perhaps "fiber to the home", where light signals carrying gigabits of data can be delivered directly to the customer. One 0.5-Watt erbium amplifier can supply an optical signal to as many as 500 homes or businesses (Figure 2a). Of course the cost of laying the fiber cable remains. However high power amplifiers can allow even these costs to be eliminated.

Companies such as Terabeam are using high power amplifiers to beam optical signals directly between offices and across cities. The amplifier is attached to a small telescope and the broad, eye-safe beam can be delivered directly to the office window enabling wireless high speed video, internet and voice communications (Figure 2b). The high amplifier power is typically held in reserve until rain or fog requires high powers to maintain the connection. Because the beam is large, birds or blowing leaves do not affect the signal.

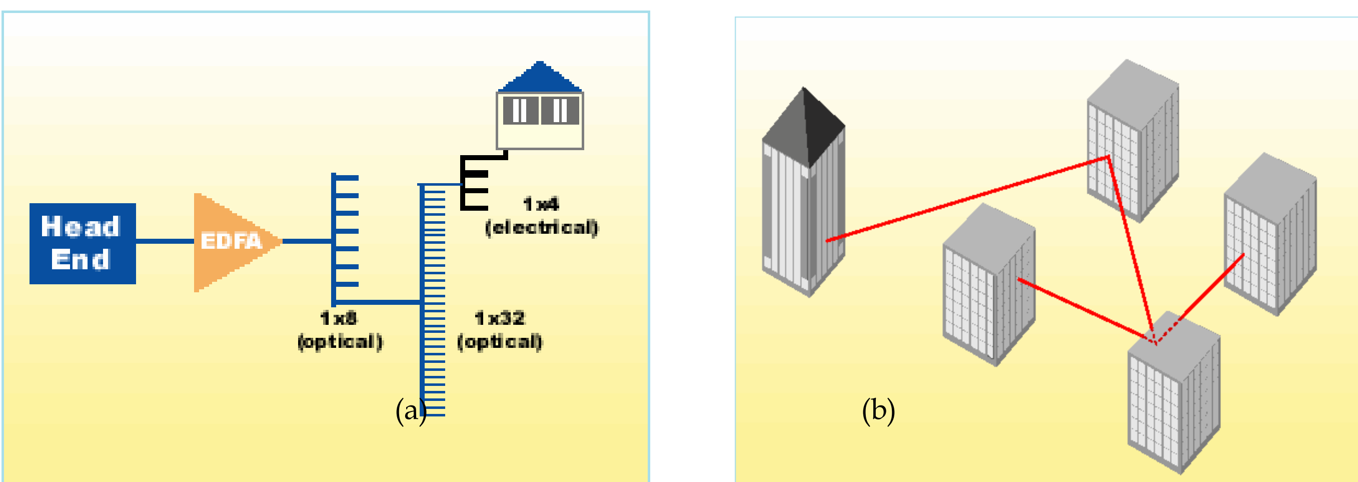


Figure 2. (a) High power erbium amplifiers (EDFA) allow one optical signal to be split between many homes (b) or be beamed directly through the air without the need for expensive cables.

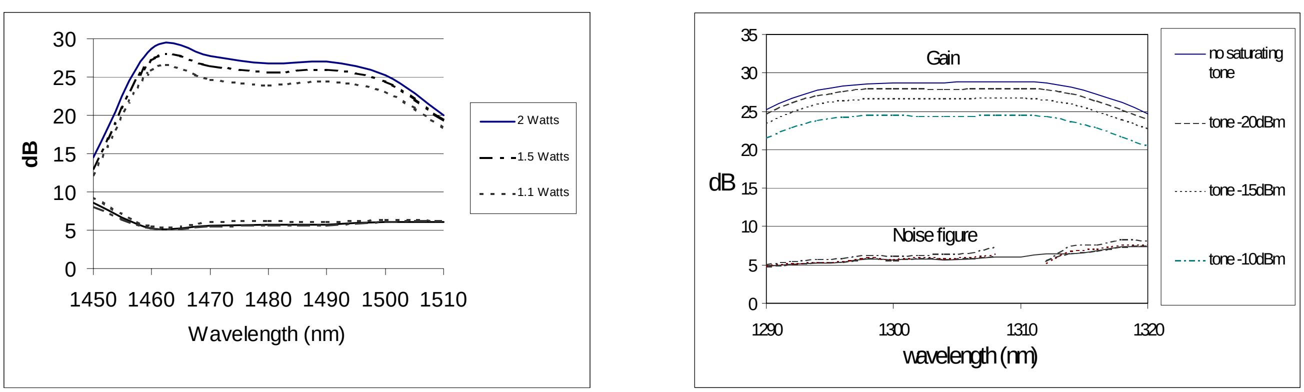
The next generation of telecommunications products

Cladding pump technology is enabling a broad range of new products. Gain flattened erbium/ytterbium amplifiers can produce gain over entire the wavelength range from 1529 nm to 1570 nm (the C-band) and from 1570 to 1610 nm (the L-band). Together these represent all the wavelengths used in most telecommunications systems. These new broad wavelength amplifiers eliminate the need for expensive single single-mode diode pumped amplifiers in the fiber-optic network backbone. Since these single-mode diode lasers represent approximately half of amplifier manufacturing costs, the savings are substantial.

Dual-wavelength Raman pump sources allow telecommunications companies to greatly reduce noise in their systems by amplifying the optical signals as they travel along the cable. These Raman laser light sources combine a ytterbium fiber laser with a fiber wavelength converting system. By using these devices, light signals can be sent through many amplifiers and more than 6000 km of optical fiber.

Ytterbium fiber lasers are an excellent source of light energy for optical amplifiers operating at new wavelengths, so far unused in telecommunications systems. Thulium doped fiber amplifiers amplify light in the S-band at wavelengths between 1440 and 1520 nm. Praseodymium doped fiber amplifiers operate between 1290 and 1320 nm. The addition of these new wavelengths more than doubles the data carrying capacity of fiber optic cables at minimal cost.

While most optical amplifiers are made from silica glass (with a small amount of rare earth added to the core), these amplifiers are made from ZBLAN, a fluoride glass. However, while the glass is different, the optical characteristics are very similar. The gain-flattened S-band amplifier was designed to produce 25 dB of gain (about 300 times amplification) and a maximum output power of 20 dBm (100 mW). The praseodymium amplifiers are designed with similar characteristic but operate at 1310 nm, a wavelength popular for cable television systems. In pre-release testing, the units are temperature cycled from -40 to +80 °C and then the splices are power tested at a laser power of between 800 mW and 1.25 Watts. Figure 3 shows multi-channel gain and noise figure measurements for both amplifiers.



(a) (b)

Figure 3. Gain and noise figure measurements on (a) 1310 nm and (b) S-band optical amplifiers.

It seems that the invention of side pumped cladding pumped amplifiers has begun a small revolution in optical communications; a revolution which continues to result in new products more than a decade later.

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